UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, ex. rel. W.A. DREW EDMONDSON, in his capacity as ATTORNEY GENERAL OF THE STATE OF OKLAHOMA and OKLAHOMA SECRETARY OF THE ENVIRONMENT, J. D. Strong, in his the capacity as the TRUSTEE FOR NATURAL RESOURCES FOR THE STATE OF OKLAHOMA, **Plaintiffs,** **v.** **TYSON FOODS, INC., TYSON POULTRY, INC., TYSON CHICKEN, INC., COBB-VANTRESS, INC., AVIAGEN, INC., CAL-MAINE FOODS, INC., CAL-MAINE FARMS, INC., CARGILL, INC., CARGILL TURKEY PRODUCTION, LLC, GEORGE'S, INC., GEORGE'S FARMS, INC., PETERSON FARMS, INC., SIMMONS FOODS, INC., and WILLOW BROOK FOODS, INC.,** **Defendants.**	**Case No. 05-CV-329-GKF-SAJ**

EXPERT REPORT OF

Timothy J. Sullivan, Ph.D.
President

E&S
Environmental
Chemistry, Inc.

January 29, 2009

Exhibit W

TABLE OF CONTENTS

List of Figures

List of Tables

I. INTRODUCTION

A. Qualifications

I have a PhD in biological sciences from Oregon State University, through a multidisciplinary program that involved three areas of focus: environmental chemistry, ecology, and zoology. I have 30 years of experience in environmental effects research, mostly focused on water quality and the impacts of human activities on water quality. I have published more than 100 peer-reviewed journal articles, books, book chapters, and technical reports describing the results of this research. I co-founded and have been President of E&S Environmental Chemistry, Inc. since 1988. We conduct environmental research and consulting projects for government, industry, and stakeholder groups. I have also been President of E&S Environmental Restoration, Inc. since 1996. We conduct on-the-ground environmental restoration projects on agricultural and forestry lands, and we also market native grass seed for ecological restoration. I have taught a graduate course in Watershed Science at Rensselaer Polytechnic Institute, NY and biological science courses at Western State College, CO. Below, I highlight some of my work experience in areas particularly relevant to the Illinois River project.

I have experience studying the influence of land use on the water quality of lakes, rivers, and streams. This includes about 20 years of experience conducting watershed assessments and spatial analyses using geographic information systems (GIS) to determine relationships between human activities in the watershed and the quality of surface waters.

I have managed multiple projects that have examined the influence of human activities on nutrient and fecal bacteria concentrations in river water. Land uses have included agriculture, forestry, rural residential development, and urban development. I have extensive experience managing and writing watershed assessments. Assessment of the contribution of nutrients and bacteria to surface waters, and the effects of such contributions on water quality, are important parts of all of our watershed assessments. Each of these assessments (10 to date) has evaluated water quality of the river system and aquatic/riparian habitat, as influenced by human activities, including forestry, agriculture, urban and residential development, and water use.

I have 10 years of experience studying the effects of agriculture, especially livestock operations, on the quality of river and estuary water and the role of Best Management Practices (BMPs) in reducing water pollution. I also have 10 years of experience managing on-the-ground ecosystem restoration projects, especially focused on riparian zones, and implementation of BMPs. Much of this work has occurred in agricultural settings.

Some relevant projects have included the following:

- Responsible for synthesis and integration and report writing for watershed assessments/analyses for the Wilson, Trask, Miami, Necanicum, Umpqua Basin (four reports), Upper Sprague, and North Santiam River watersheds in Oregon.
- Principal investigator of project for U.S. Department of Energy to investigate the roles of land use and landscape in the chemistry of surface waters. Involved evaluation of disturbances in the watersheds and comparing them with the chemistry of the lakes.
- Served as project manager for a modeling project to assess aquatic and terrestrial effects of air pollutants in the eight-state southern Appalachian Mountains region for the Southern Appalachian Mountains Initiative (SAMI). Involved investigation of

relationships between landscape characteristics (geology, soils, vegetation, elevation, ecoregion) and water chemistry for over 900 streams.

- Assisted the U.S. Environmental Protection Agency (U.S. EPA) to select candidate lakes throughout the United States for possible inclusion as reference waters in the National Lakes Survey, conducted during the summer of 2007. Involved examination of water quality data, construction of maps of land use and land cover within the watersheds of candidate lakes, and examination of aerial photographs of lakeshore areas.

- Served as project manager for several water quality monitoring projects (1996 to 2004) conducted for the Tillamook Bay National Estuary Project and Tillamook Estuaries Partnership to evaluate the concentrations and loads of nutrients, sediment, and fecal coliform bacteria (FCB) in the five rivers that flow into Tillamook Bay, Oregon. These projects include long-term monitoring, storm monitoring, demonstration of environmental remediation, pollutant source area identification, and evaluation of the relationships between land use and water quality.

- Managed demonstration project on agricultural land adjacent to Tillamook Bay, OR to reduce nonpoint source pollution in a cooperative effort with land owners. Included hydrological modifications, wetland enhancement, riparian fencing and planting, culvert replacement, and changes in manure management practices, along with extensive, storm-based water quality monitoring of treatment and reference (control) watersheds.

- Managed research project to quantify the fecal bacteria removal efficiencies of vegetated buffer strips. Research was funded by the U.S. EPA, Oregon Department of Environmental Quality, Tillamook Estuaries Partnership, and Oregon State University Agricultural Research Foundation. Experimental design included buffer strips ranging from 1- to 25-m width on different slope classes, along with zero buffer treatment cells and control cells. Dairy cow manure was applied (all except control cells) to pasture at the uphill buffer interface in advance of storms. Runoff was collected at the downhill buffer interface during rainstorms over a two-year period.

- Managed numerous multidisciplinary watershed restoration projects for the U.S. Forest Service, Bureau of Land Management, Tillamook Estuaries Partnership, and Oregon Department of Fish and Wildlife (1996-2006), including erosion control, riparian planting, fish habitat enhancement (large woody debris and boulder placement and attachment in streams), sensitive vegetation protection, culvert replacement, livestock fencing, road decommissioning, noxious weed survey and eradication, and stream surveys.

- Managed project for the U.S. Environmental Protection Agency to prepare an assessment of environmental effects of emissions and deposition of oxides of nitrogen and sulfur for the 2008 review of National Ambient Air Quality Standards to protect against environmental impacts associated with nutrient enrichment and acidification. Served as primary author of draft materials, including Integrated Science Assessment and associated effects annexes, totaling more than 1,200 pages.

B. Data and Information Considered

I have read the reports submitted by many of the Plaintiffs' consultants for this case, including reports prepared in conjunction with the Preliminary Injunction and more recent reports. These have included reports prepared for this case by Drs. Caneday, Fisher, Olsen, Welch, Cooke, Harwood, Stevenson, and Engel, and also the report prepared by Mr. Brown. I have also read deposition transcripts for many of these consultants. I have read expert reports prepared on behalf of the Defendants in this case. I have read or referred to a large number of journal articles and reports that provide information relevant to some of the topics considered for this case. I have considered available data collected for this case and reported by Dr. Olsen, as well as data from other sources, including the U.S. Geological Survey, U.S. Environmental Protection Agency, Oklahoma Water Resources Board, and others. I have also considered various geographic data layers that could assist in interpretation of spatial patterns in water quality, including information on hydrography, precipitation, land use, soils, livestock populations, and human populations.

C. Previous Testimony

I have previously, within the past four years, prepared expert reports and testified at deposition and/or trial in the following cases:

United States of America, et al. v. Westvaco

Preliminary Injunction hearing for this case

D. Rate of Compensation

My compensation for time I have spent on this case has been approximately $173 per hour.

II. OVERVIEW OF PRINCIPAL OPINIONS

This report offers a series of expert opinions regarding alleged sources of contamination of surface waters in the Illinois River Watershed (IRW) in northeastern Oklahoma and northwestern Arkansas. I have been retained by the Defendants in this case. I therefore reviewed available data and documents relevant to these matters, examined the watershed in question, supervised analyses of existing data (including data collected on behalf of the Plaintiffs in this case) and reviewed documents prepared by various consultants and experts for both the Plaintiffs and Defendants. I wish to offer the following major opinions. My opinions are based on material that I have examined up to the date of preparation of this report. I reserve the right to modify these opinions as new information becomes available.

This section of my report provides an overview of my principal opinions in this case. The following section provides a more in-depth discussion of each of these principal opinions. There are two appendices. The first provides some additional responses to selected claims made by some of Plaintiffs' consultants in their reports for this case. The second provides a copy of my resume. My principal opinions are as follows:

1. *The most important water quality issues regarding stream waters within the IRW are phosphorus (P) concentration and fecal indicator bacteria concentrations.*

2. *The concentrations of P and fecal indicator bacteria in stream waters in the IRW are not unusual. Similar values are commonly found throughout Oklahoma, the region, and the nation.*

3. *Land use in the IRW is a complex mixture of rapidly expanding urban areas, rural residential housing, pasture land, and forest. Such a mix of land use, with or without poultry operations, is expected to be associated with contributions of point and nonpoint source (NPS) pollution, including P and fecal indicator bacteria, to stream waters.*

4. *There are large numbers of people and their animals in the IRW. Plaintiffs' consultants failed to fully consider the importance of people, cattle, and other animals as sources of nutrients and fecal indicator bacteria to stream waters. There were approximately 272,000 people living in the IRW as of 2005, and that number has been increasing rapidly in recent years. There are also approximately 200,000 cattle and 166,000 swine (Clay 2008) in the IRW. People, and their activities and animals, are well known and documented sources of P and fecal indicator bacteria to stream water. Plaintiffs' consultants did not fully consider these sources of P and fecal indicator bacteria to streams.*

5. *Waste water from municipal treatment plants in urban areas is a major source of P to surface waters in the IRW. Examination of spatial patterns of P concentration in streams within the IRW shows stronger correlations with waste water treatment plants (WWTPs) and urban areas than with agricultural lands.*

6. *Within non-urban areas, there are multiple possible sources of P and/or fecal indicator bacteria to streams. These include, in addition to the poultry operations that Plaintiffs'* ***assume*** *to be the source of these constituents, the following: cattle, rural residential septic systems and lawns, other livestock and pets, roads and associated ditches, other sources of erosion, recreational sources, and fertilizer use. Plaintiffs' consultants largely ignore these other sources of P and bacteria within rural portions of the watershed. In particular, they dismiss the importance of cattle, erosion, and septic systems without adequate basis.*

7. *Plaintiffs' edge-of-field water samples have not, as Plaintiffs claim, been shown to represent the water quality of runoff coming off poultry litter-amended fields and subsequently entering streams. Rather, Plaintiffs' edge-of-field samples appear to represent some unknown mix of ditch water (of unknown origin and ultimate fate), ephemeral stream water, and roadside or pasture-edge puddles. No evidence is provided by Plaintiffs' consultants to document where the water that they sampled and labeled as "edge-of-field" flowed from or flowed to; what human and animal activities may have contributed P, bacteria, or other constituents to that water; what the specific sources to that water of P or fecal indicator bacteria may have been (i.e., cattle manure, road erosion, septic systems, fertilizer, other livestock manure); or whether that water eventually was contributed to a stream, and if so whether it was contributed in sufficient quantity so as to appreciably alter the quality of that stream water.*

8. *Plaintiffs' consultants claim to have demonstrated empirical correlations between their estimates of poultry house densities within selected subwatersheds and total P (and other variable) concentrations in stream waters. They fail to explain, however, that such spatial correlations merely suggest that (if one assumes that their suspected locations of active poultry houses are accurate) there was a tendency for P concentrations to be higher in*

locations that contain more poultry houses as compared with locations that contain fewer poultry houses; there is no evidence that one causes the other to occur. Importantly, it is not true, despite Plaintiffs' consultants claims to the contrary, that their purported demonstration of a statistically significant correlation between two variables demonstrates that a cause and effect relationship exists. They also fail to explain, or dismiss the importance of, the fact that the density of poultry houses is itself correlated with other variables that reflect known important sources of NPS pollution, namely density of cattle, density of septic systems, and density of roads. Thus, Plaintiffs' consultants' poultry house density variable is a surrogate for human impacts of a variety of kinds in agricultural settings, any of which might contribute NPS pollution to streams in the IRW. Plaintiffs' consultants' (Drs. Engel and Stevenson) correlations do not demonstrate that poultry operations cause or contribute to P in stream water.

9. *Phosphorus and fecal indicator bacteria are generally not very mobile in soils; their presence in, or at the edge of, a field or in a ditch does not indicate that these variables are transported to a stream in sufficient quantity to have an appreciable effect on stream water quality. Plaintiffs' consultants fail to demonstrate that their measured concentrations of P and fecal indicator bacteria in litter, soil, or edge-of-field samples have any influence on measured concentrations of these constituents in stream waters. Thus, Plaintiffs' consultants do not provide fate and transport documentation for their assertion that constituents that might be present in poultry litter in a barn or on a field, or in fact any of those constituents that might move into the surface soil on that field or the ditch water adjacent to that field, ever actually move to a stream or to Lake Tenkiller in quantities sufficient to affect water quality.*

10. *The concentrations of P and fecal indicator bacteria in stream water are strongly dependent on water flow, such that concentrations tend to be higher under high flow conditions as compared with low flow conditions. Furthermore, fecal indicator bacteria concentrations are dependent on stream order such that concentrations of fecal indicator bacteria are higher in the smaller (low order) streams as compared with the larger (higher order) streams. These observations have important implications relative to interpretation of water quality data. In particular, it can be difficult or impossible to determine whether or not conditions are changing over time unless consideration is given to differences in flow among the sampling occasions. Differences in flow and stream order also impact interpretation of exceedances of fecal indicator water quality standards and the likelihood of human exposure via primary body contact recreation to the measured water quality conditions.*

11. *Scientific research indicates that P and fecal indicator bacteria are generally contributed from pasture lands to stream waters under particular conditions, mainly in areas immediately adjacent to streams and on pasture soils that routinely flood during rainstorms. Existing state and federal guidelines and regulations target such areas by discouraging or prohibiting land application of poultry litter. This is done to minimize the potential for contamination of surface waters with nutrients, bacteria, and other constituents.*

12. *Plaintiffs' consultant, Dr. Olsen, incorrectly claimed that his principal components analyses (PCA) identified two major sources of contamination in the IRW (poultry litter and WWTP effluent) and that poultry litter is by far the dominant contamination source. In fact, Dr. Olsen's PCA analyses were not able to discriminate among the various sources of P or fecal indicator bacteria to streams in the IRW.*

13. *There are many sources of P and fecal indicator bacteria to steams in the IRW. Plaintiffs' consultants do not adequately address the role of these sources and provide no scientifically valid evidence that the spreading of poultry litter in the IRW is a source of these constituents to stream waters.*

14. *Plaintiffs' consultants compared chemical and biological conditions in the IRW to hand select "reference" reservoirs and streams. Such reference watersheds were selected by Plaintiffs' consultants to represent relatively pristine conditions, based on low concentrations of P in surface water, and are therefore expected to be relatively free of impacts of people and their animals. Such watersheds are not appropriate indicators of what the IRW would be like, in the absence of poultry operations.*

15. *Despite claims by Plaintiffs' consultants to the contrary, water quality in the IRW has not been deteriorating over time in recent years. Based on trends in total P, it appears that water quality may, in fact, have improved in recent years.*

16. *Plaintiffs' consultants contend that the concentrations of P in the sediments of Lake Tenkiller illustrate an increase over time since about 1960 that corresponds temporally with an increase in the poultry population in the IRW, more than with increases in the populations of humans or cattle in the watershed. My reanalysis of the relevant data illustrates that the populations of poultry, humans, and cattle have all increased in roughly similar fashions, and that any or all of these population trends correspond with the change in sediment P concentration alleged by Plaintiffs' consultants.*

17. *Plaintiffs' consultants assert, on the basis of mass balance calculations by Meagan Smith that were reported by Dr. Engel, that more P is imported into the IRW in the form of feed for poultry than is either imported in other forms or exported from the watershed at the Lake Tenkiller spillway. On this basis, Plaintiffs' consultants incorrectly conclude that P imported into the watershed by the poultry industry is a (the) dominant source of P to streams within the IRW. Even if Ms. Smith had performed her calculations correctly, the mere importation of P into the watershed does not determine the extent to which P moves from land to stream. Plaintiffs' consultants totally ignore transport processes despite extensive scientific research indicating their critical importance.*

18. *Plaintiffs' consultants sampled water that they labeled as spring water and that was purported to represent the quality of water coming out of the ground. But some of these samples were actually collected some distance downhill from where the spring emerged from the ground. Plaintiffs' consultants incorrectly interpret the results of analyses of these samples as representative of ground water quality. This "spring" water is potentially contaminated with other known land-based sources of NPS pollution, particularly associated with cattle and other livestock. Furthermore, video footage of sampling activities at one spring site revealed Plaintiffs' field staff stepping in the water that they were in the act of collecting; such a violation of standard sampling protocols cast doubt on the adequacy of the field staff training and oversight provided by Plaintiffs' consultants to their field crews. This is important because the concentrations of P are generally very low (less than 1 mg per liter) and fecal indicator bacteria are extremely small. As a consequence, results can be influenced by a contamination error. Some of the key analyses presented by Plaintiffs' consultants, including regressions with poultry house density (Dr. Engel) and principal components analysis of potential source areas (e.g., cattle influence; Dr. Olsen), are dependent on analytical results for only a few water samples.*

19. *Existing state and federal guidelines and regulations were crafted to minimize the potential for surface water contamination as a consequence of spreading poultry litter on pastureland. Many of these guidelines are recent. Plaintiffs present no evidence to suggest that farmers are not following these guidelines or that these guidelines are not having their intended result, which is protection of water quality.*

20. *Based on my examination of various reports and testimony of Plaintiffs' consultants in this case, they apparently set out to try to prove that poultry litter spreading is the cause of stream and lake pollution in the IRW. They failed to adequately consider the multitude of human activities and land uses found in the IRW that are known to be important sources of point and nonpoint pollutants to surface waters. There are many examples where they lump what are undoubtedly multiple pollutant sources into what they label as poultry-derived pollution. They minimize the influence of other known sources of point and nonpoint source pollution of stream water. Thus, their analyses in many cases are not representative of the relative importance of the various potential sources of P and fecal indicator bacteria in the IRW. Rather, their effort appears to be biased so as to maximize the perceived importance of NPS pollution that they then attempt to assign without adequate basis to poultry operations.*

21. *There is an entire field of scientific study that attempts to determine the potential for P loss from pasture land to streams. This research provides the foundation for litter management in the IRW today. It is well known and widely recognized that P loss potential is dependent on an array of site condition and management factors, as well as loading factors. Plaintiffs ignore this body of scientific knowledge in their efforts to discontinue land application of poultry litter in this watershed.*

22. *Plaintiffs' consultants provide no scientifically defensible evidence in support of their contention that poultry litter spreading is the dominant, or even an appreciable, source of P or fecal indicator bacteria to stream or lake waters in the IRW. Neither their principal components analysis nor their edge-of-field sampling effort was able to discriminate among the potential sources of P and fecal indicator bacteria to stream water. Spatial patterns in their stream sampling data do not discriminate among the potential sources of these constituents within the non-urban portions of the IRW, and in fact suggest that the dominant sources of P to streams within the watershed occur in or near the urban areas and/or the WWTP facilities.*

23. *Plaintiffs' consultant, Dr. Olsen, lists 22 substances in his report for this case that he claims are both hazardous and are contained in poultry litter. But Dr. Olsen provides no analyses to conclude that there have been injuries from these substances, other than P, that have been or may have been associated with application of poultry litter in the IRW, or that these substances are contributed to the streams in the IRW as a consequence of land application of poultry litter, or that these substances are associated with eutrophication of waters in the IRW.*

III. DESCRIPTION OF MAJOR OPINIONS

1. Focus on P and fecal indicator bacteria

Dr. Stevenson (2008, page 10) states that he uses total phosphorus (TP) as his primary indicator of nutrient enrichment for evaluations done for his report in this case. Dr. Fisher (May; 2008b), in his summary of opinions of his expert report, states that:

> ***the contaminants of concern within the Illinois River Watershed are phosphorus and bacteria.***

This claim was reiterated in his deposition (September 4, 2008, page 451, and again on page 516, and pages 615-616).

In EPA's revised Confined Animal Feeding Operations (CAFO) Rule, published in 2003 (U.S. EPA, 2003, page 7192), which applied in part to litter management for poultry operations defined as CAFOs, P was identified as "the pollutant of most concern". The Comprehensive Basin Management Plan for the Oklahoma portions of the IRW (Haraughty 1999, page 27) concluded that streams in the IRW are P-limited.

Most ecological concerns alleged by Plaintiffs' consultants in this case, including eutrophication of stream and lake water and reduction of dissolved oxygen, focus on aspects of water quality that Plaintiffs' consultants claim are directly or indirectly associated with concentrations of total P in surface waters. I agree with Plaintiffs' consultants Drs. Stevenson, Olsen, Fisher, Cooke, and Welch that the principal constituent of concern in the IRW is TP and that fecal indicator bacteria are also of interest. Other chemical and physical variables are either claimed to be partial components of the ecosystem response to P (for example, in some cases dissolved oxygen, chlorophyll, transparency) or are not expected to have much influence on overall ecosystem health, in comparison with P.

The existing water quality criterion for P concentration in streams classified as Scenic Rivers within the IRW is based on measurement of total P, rather than some dissolved form or a form that is expected to be especially biologically available (such as soluble reactive P, SRP, for example). For portions of the Illinois River and some of its major tributaries, the applicable water quality standard is 0.037 mg/L of TP, calculated as a geomean (geometric mean) of what would typically be at least five samples collected over a 30-day period **(http://www.oar.state.ok.us/viewhtml/785_45-5-19.htm)**. This standard applies to portions of the Illinois River and its tributaries that are designated as Scenic Rivers. Although it is possible to evaluate multiple forms of P, I focus here on total P because this is the basis for the water quality standard and because under certain conditions it is possible for P to exchange among its various forms in the environment. Although the focus is on total P, only a portion of that P is considered to be biologically available within the stream and lake systems.

Under the Clean Water Act, lakes and streams can be listed as water quality impaired, or placed on the 303(d) list, based on designated beneficial uses. Within the context of this case, one of the beneficial uses of river water that is of greatest interest is Primary Body Contact Recreation. This involves direct body contact with the water, for example when swimming, where a possibility of ingestion exists. In a lake or stream designated for the Primary Body Contact Recreation beneficial use, there are limits set for fecal indicator bacteria concentrations during the recreational period May 1st to September 30th.

Streams in Oklahoma can be listed as water quality impaired for Primary Body Contact Recreation based on one or more of three indicators of possible fecal contamination: fecal coliform bacteria (FCB), *Escherichia coli* (*E. coli*), and enterococcus. *E. coli* is a subset of FCB. In each case, the determination is made as to whether a body of water is to be listed as impaired on the basis of the geomean of a minimum of five samples collected within a period of not more than 30 days. The geomean standards for FCB, *E. coli*, and enterococcus are 200, 126, and 33 colony forming units (cfu) per 100 ml of water sample, respectively. The geomean calculation minimizes the influence of occasional very high values of bacteria concentration that commonly occur in surface water samples. Such high values can result from high ambient stream concentration at the time of sample collection, laboratory or field contamination of the water sample, or the presence of one or more fecal particles in the water sample. There are also requirements that no more than 10% of the samples collected in a 30-day period exceed 400 cfu/100 ml of FCB and that no individual sample exceed 406 cfu/100 ml of *E. coli* or 108 cfu/100 ml of enterococcus. (These single sample limits are lower for lakes and high-use water bodies: 235 and 61 cfu/100 ml, respectively.) Assessment of compliance with standards on the basis of geomean statistics is preferable to assessment of compliance on the basis of single samples, which can be affected by laboratory error or inclusion of a fecal particle (from wildlife, livestock, or human source) in the water sample. Intra- and inter-day variability can be high. Gibb (2008) also stated that it is the long-term geometric mean bacterial concentration that is of interest and that little information can be obtained from analysis of a single water sample for determination of fecal indicator bacterial concentration.

The approach to evaluation of compliance with Primary Body Contact Recreation standards in Arkansas is different. It is based only on FCB. According to the Arkansas standard, between May 1st and September 30th, the FCB geomean shall not exceed 200 cfu/100 ml and not more than 10% of the samples within a 30-day period shall exceed 400 cfu/100 ml. Arkansas also has designated Secondary Contact Waters, used for boating and fishing, in which the FCB geomean shall not exceed 1,000 cfu/100 ml and not more than 10% of the samples taken in any 30-day period shall exceed 2,000 cfu/100 ml.

Compliance with fecal indicator bacteria water quality criteria for supporting beneficial uses can therefore be based on evaluation of fecal coliform bacteria, *E. coli*, or enterococcus. I focus here mainly on *E. coli* because it is commonly measured in surface waters and because it is a more consistent predictor of gastrointestinal illness in humans as a consequence of exposure in fresh waters than enterococcus, fecal coliform, or other bacteriological indicators (Wade et al. 2003).

Furthermore, nearly all (more than 90%) of the stream sites in Oklahoma that have been sampled for enterococcus, and for which data are readily available, have geomean enterococcus concentrations above the 33 cfu/100 ml standard. Defendants' expert, Dr. Myoda reported similar results for the state of Delaware(Myoda 2008). Thus, enterococcus is not an effective screen for identifying streams having unusually high concentrations of fecal indicator bacteria in Oklahoma.

For the reasons outlined above, most, but not all, of the analyses and discussion presented in this report are focused on TP and *E. coli*. Furthermore, where possible the focus is on the geomean of multiple measurements. Results of analyses of single samples provide little information regarding the extent to which a water body may or may not exhibit elevated concentrations of fecal indicator bacteria.

One must be careful not to over-interpret the meaning of a single or a few high values of fecal indicator bacteria in stream water. Because bacteria are extremely small, and therefore because bird and mammal feces can contain so many of them, high values of fecal indicator bacteria concentration in a water sample from a stream can derive from inadvertent inclusion of one or a few fecal particles in the water sample. A fecal particle in a water sample can come from a multitude of sources, including duck, goose, livestock, rodent, human, beaver, or deer. Samples of water that are analyzed for bacteria also have the possibility of inadvertent contamination of the sample with bacteria either by field personnel or in the laboratory. A single high value for bacteria (which can substantially skew an average concentration) has little or no meaning. This is largely why bacterial standards are based on calculation of a geomean (which is not heavily skewed by a single high value) of five or more samples.

2. *Concentrations of P and fecal indicator bacteria in the IRW are similar to streams and reservoirs commonly found elsewhere in Oklahoma, the region, and the nation.*

Plaintiffs' consultants allege that concentrations of P and fecal indicator bacteria are high in the waters of the IRW. Nevertheless, they do not adequately compare such measurements with data collected elsewhere. Of interest in this regard are concentrations throughout the state of Oklahoma, the ecoregions in which the IRW is located, the general region of the country in which the IRW is located, and the United States as a whole. I did compile available data, examine publications, and conduct analyses to illustrate such comparisons. Results are described below.

Spatial Patterns in Oklahoma

Failure to support water quality beneficial uses is quite common in Oklahoma. For example, the Oklahoma Water Resources Board has established an ambient monitoring network of 100 active permanent water quality monitoring stations which are evaluated annually. According to the Beneficial Use Monitoring Program (BUMP) Draft 2007 Streams Report (OWRB 2007), only 11 of those monitoring sites fully supported the primary body contact recreation beneficial use during that year. The Oklahoma Water Quality Assessment Integrated Report for 2004 (ODEQ 2004) designated 33,221 miles of rivers and streams in the state as having the beneficial use of primary body contact recreation. Of those river and stream miles, only 471 miles were determined to be fully supporting the beneficial use, and 6,546 miles were determined to be not supporting the beneficial use. The remaining miles were not assessed or were judged to have insufficient information. Thus, of the river and stream miles determined by the state of Oklahoma to be either supporting or not supporting the primary body contact recreation standard, 93% were judged to not support this beneficial use.

Figures 2-1 through 2-3 show the concentrations of total P in stream water at sampling sites throughout Oklahoma. Data are presented as the geomean of available data for all sites represented by five or more samples during the period 2000 to 2007. Three separate maps are shown, representing three different sources of data: U.S. Geological Survey, EPA STORET, and Oklahoma Water Resources Board. These maps show that stream water total P concentration is highly variable throughout the state of Oklahoma, regardless of which major data source we examine. Concentrations of total P in stream water inside the IRW are not appreciably different from streams outside the IRW. The occurrences of concentrations above the 0.037 mg/L Oklahoma water quality standard for Scenic Rivers are no more prevalent inside the IRW as compared with outside the IRW. Note that sites that have geomean total P concentration higher than the standard are shown on the maps as orange bars; green bars indicate that the geomean concentration at a given site is not above the standard.

Impacts to surface waters by fecal bacteria derived from mammals and birds is a widespread phenomenon throughout the United States, and such contamination is commonly identified using indicators of fecal inputs, especially FCB and *E. coli*. For example, there were 8,695 miles of stream listed by the state of Oklahoma as water quality impaired (303(d) list), and 70% of those stream miles were listed as a consequence of fecal bacteria contamination. Thus, fecal bacteria contamination was the most common cause of stream impairment listing in Oklahoma. Nevertheless, it is important to note that the presence of indicator bacteria does not mean that human exposure to that water will cause illness. Water pollution with waste material of human origin is the more significant public health concern because human feces is more likely to contain human-specific microbes (DuPont 2008). EPA recommended the *E. coli* standard (geometric mean of 126 cfu/100 ml) based on studies at fresh water beaches at Lake Erie, PA and Keystone Lake, OK. At both locations, there was nearby human sewage discharge (c.f., DuPont, 2008). The standard was not selected based on exposure to bacteria of non-human origin, such as for example from cattle, poultry, or other livestock. National Research Council (2004, page 173) concluded that because:

> ***animals shed bacterial indicators without some of the accompanying human pathogens, there is considerable uncertainty in extrapolating present standards to nonpoint source situations.***

Figure 2-4 shows the stream reaches in Oklahoma that were included in the 2006 draft 303(d) list for not supporting the primary body contact recreation beneficial use, based on having measured concentrations of one or more of the fecal indicator bacteria types above the designated values for classifying waters as impaired. It is my understanding that additional stream segments within the IRW have been included on the 2008 Oklahoma 303(d) list, but I do not have the spatial data that would allow those additional listed stream segments to be mapped at the time of preparation of this report. Oklahoma stream reaches that are listed for primary body contact recreation (bacteria) are shown in Figure 2-4, including the basis for listing: FCB, *E. coli*, and/or enterococcus. Such listings for fecal indicator bacteria are widely distributed throughout the state, including portions of the state that do, and those that do not, contain extensive poultry operations.

Figure 2-5 shows the distribution of poultry farming, by county, from the agricultural census and information provided by Dr. Billy Clay (pers. comm. 2008). The poultry industry is primarily confined to eastern Oklahoma, whereas 303(d) listings for bacteria and the occurrence of concentrations of FCB, *E. coli*, enterococcus, and total P above surface water standards are widespread throughout the state. There is no obvious spatial link between counties in Oklahoma that have large concentrations of poultry and locations of streams shown to have concentrations of total P or fecal indicator bacteria above water quality standards. Concentrations of these constituents above water quality standards occur commonly statewide irrespective of the spatial distribution of poultry farming activities.

The concentrations of fecal indicator bacteria in the IRW are high enough to result in 303(d) listings at some locations, but these concentrations are not unusually high, compared with values elsewhere. Again, using the state of Oklahoma as the example, concentrations above standards of all three of the bacterial indicators addressed in the state's request for a preliminary injunction are found to be well distributed throughout Oklahoma (Figures 2-4 through 2-17). Concentrations within the IRW are not higher than are commonly found elsewhere throughout the state. This pattern holds for enterococcus (Figures 2-6 and 2-7; note that enterococcus data are not available from USGS], FCB (Figures 2-8 through 2-10), and *E. coli* (Figures 2-11 through 2-13). The spatial patterns of fecal indicator bacteria concentrations in Oklahoma are not consistent with the proposition that poultry litter is an important source of these fecal bacteria indicators. Rather, concentrations of these indicators above standards appear to be common throughout Oklahoma, in areas where poultry operations are numerous and in areas where poultry operations are scarce (Figure 2-5).

Furthermore, there are many locations throughout Oklahoma where fecal indicator bacteria concentrations are substantially higher than they are in the IRW. The fact that portions of the Illinois River and its tributaries are listed as water quality impaired as a consequence of fecal indicator bacteria concentrations is not a cause for alarm. The issue is well known and is nationwide in scope.

Data presented for individual data sources (e.g., USGS, OWRB, STORET) in many of the preceding figures are combined into four maps, one for TP and one for each of the fecal indicator bacteria variables. These data are shown in Figures 2-14 through 2-17**.** The spatial patterns in the data are very clear, indicating that neither the concentration of P nor the concentration of any of the three fecal bacteria indicators is high in the IRW, compared with elsewhere in Oklahoma. Furthermore, the few instances of relatively high concentrations within the IRW occur adjacent to, or shortly downstream from, municipal waste water treatment facilities.

Concentrations of enterococcus above the Primary Body Contact Recreation standards are ubiquitous within the IRW. Similarly, enterococcus concentrations are above the Primary Body Contact Recreation standard at 90% (OWRB data) to 96% (STORET data) of the locations within Oklahoma where sufficient data are available to calculate a geomean of five samples (Figures 2-6 and 2-7). This suggests that either poultry litter is not the principal source of enterococcus to stream water or that poultry litter application is a common occurrence statewide. The spatial distribution of poultry operations within Oklahoma from agricultural census data (Figure 2-5) shows that poultry farming is confined primarily to eastern Oklahoma. Thus, consideration of the spatial patterns in enterococcus concentrations and poultry farming suggests that sources of enterococcus other than poultry are commonly responsible for the frequent occurrence of concentrations above the standards.

As illustrated in the series of maps described above, any allegation that TP or fecal bacteria indicator concentrations in the IRW are unusually high compared to other water bodies in Oklahoma, thereby representing an immediate and unusual health threat, is not borne out by the available data.

Stevenson (2008, page 17) reported that the median concentrations of total P in IRW streams were 0.076 mg/L in summer 2006, 0.057 mg/L in spring 2007, and 0.067 mg/L in summer 2007. The median for streams sampled by Plaintiffs' consultants for this case and reported in Dr. Olsen's database, under all flow conditions, was similar, 0.062 mg/L. Dr Stevenson (2008, page 17) concluded that these concentrations were:

> ***…relatively high in the IRW compared to many other regions***

But he did not discuss results from other regions and provided no basis or context for this statement. I have examined total P data from several large surveys and assessments, and found that concentrations of total P in the IRW are not unusual compared with data from many other locations. These results are summarized below.

Regional and National Patterns

EPA's 2000 National Water Quality Inventory Report (U.S. EPA, 2002) found that 39% of assessed stream miles and 45% of assessed lake area in the United States were impaired and did not fully achieve the water quality standards set for them. The leading sources of impairment reported by the states in 2000 were agricultural activities, hydrologic modifications (such as channelization, dredging and flow regulation), municipal sources, and urban runoff/storm sewers. Of the 88,679 miles of stream assessed for swimming use support, 28% of the assessed stream length was impaired by fair or poor water quality conditions. Litke (1999), in a review of P control measures and their effects on water quality in the United States for the USGS, stated that downward trends in P concentrations have been identified in many streams since 1970, but that:

> ***median total phosphorus concentrations still exceed the recommended limit of 0.1 milligram per liter across much of the Nation.***

They presented data that they summarized for the period 1990 to 1995 from EPA's STORET database, indicating that 32% of the hydrologic units in the conterminous United States had more than half of their measured values of TP exceeding the recommended value of 0.1 mg/L (which is 2.7 times the Oklahoma standard applicable to portions of the IRW, and is higher than the median values quoted above for the IRW [based on data summaries by Dr. Stevenson and Dr. Olsen]). Thus, contribution to surface waters of nutrients and fecal indicator bacteria is a national issue, and it has many causes. The IRW does not seem to me to be unusual in this regard.

I examined several large regional or national databases to evaluate whether concentrations in the IRW of TP or fecal indicator bacteria are unusual. Results of that inquiry are summarized below. There are certainly examples of lakes and streams in the region and in the nation that have values of these parameters that are lower than have been observed in streams and in Lake Tenkiller in the IRW. Nevertheless, as is shown by the data summarized below, concentrations of TP and fecal indicator bacteria equal to or higher than those measured in the IRW are commonplace.

Lakes

Graham et al. (2004) reported nutrient concentrations for 219 lakes in Missouri, Iowa, northeastern Kansas, and southern Minnesota. Median TP concentrations, by region, were reported as:

Ozark Highlands, 0.012 mg/L

Osage Plains, 0.045 mg/L

Dissected Till Plains, 0.079 mg/L

Western Lake Section, 0.141 mg/L

Based on the recent data summarized by Cooke and Welch (2008), the lacustrine (lake-like) portion of Lake Tenkiller for the period 2005 to 2007 has TP about equal to the median for the Ozarks Highlands and substantially below the medians for any of the other regions investigated by Graham et al. (2004).

Jones et al. (2004) reported water quality data for 135 reservoirs in Missouri, collected during the period 1978 to 2002, representing the range of reservoir resources within the state. Samples were collected near the respective dams, in the lacustrine portions of the reservoirs. The median total P concentration was 0.039 mg/L; 25% of the reservoirs had total P concentration higher than 0.058 mg/L. These data for Missouri reservoirs can be contrasted with data from Lake Tenkiller, as summarized by Cooke and Welch for their sample site near the dam (LK-01). The average TP data for site LK-01 reported by Cooke and Welch (2008, their Figure 7) was as high as 0.027 mg/L in 1974, but has decreased markedly in recent years, with values of 0.010, 0.012, and 0.011 mg/L during the most recent three years that were sampled by Plaintiffs' consultants for this case. Thus, the average TP at the dam location in Lake Tenkiller in recent years is less than one-third of the median value for representative reservoirs in the state of Missouri; nearly 75% of the reservoirs sampled in Missouri by Jones et al. (2004) have TP that is about double or more the concentration found in Lake Tenkiller.

Haraughty (1999, page 89), in the Comprehensive Basin Management Plan concluded that:

> ***Lake Tenkiller is still in fairly good shape.***

Based on analyses presented by Drs. Horne (2009) and Connolly (2009), Haraughty's (1999) conclusion appears to still apply to the lacustrine portion of the lake.

Streams

The U.S. EPA's Wadeable Streams Assessment (WSA) surveyed 1,392 (generally first through fifth order) streams throughout the United States (U.S. EPA, 2006). Sampling sites were chosen using a probability-based sampling design, such that results could be used to represent the population of streams within the sample frame, rather than just those selected for sampling. Water samples were collected during summer in the period 2000 to 2004. Although the study was not designed to make population estimates for individual states, there were 57 stream sites surveyed in Oklahoma and Arkansas. The median concentration of total P in streams that were sampled in these two states was 0.047 mg/L and the 75th percentile was 0.147 mg/L. At the national level, the median total P concentration was 0.028 mg/L and the 75th percentile was 0.077 mg/L. Thus, for both the two states (Oklahoma and Arkansas) and for the United States as a whole, the median concentrations of TP reported by Stevenson (2008,) for IRW streams were roughly between the median and 75th percentiles reported by EPA in the Wadeable Streams Assessment. That means that somewhere between one-fourth and one-half of the streams in the United States, and of the streams sampled by the WSA in Oklahoma and Arkansas, contained higher total P concentrations than were reported by Stevenson (2008) for the IRW. In general, streams within the Southern Appalachian ecoregion (median TP equal to 0.015 mg/L), and the Ozark and Ouachita segment of the Southern Appalachian Mountain ecoregion (median TP equal to 0.011 mg/L), had lower concentrations of P than streams throughout Oklahoma and Arkansas. This pattern is likely due at least in part to differences in the amounts of forested and developed lands. For example, our GIS analyses indicate that the 34 watersheds sampled by EPA in the WSA within the Ozark and Ouachita Mountains portion of the Southern Appalachian Mountain Ecoregion are 72% forested (compared with 43% in the IRW). Only 0.6% of the land within the Ozark/Ouachita watersheds sampled by EPA is developed-urban land (compared to 3.1% [five times higher] in the IRW). Thus, the streams sampled by EPA in the Ozark/Ouachita region appear to be less impacted by human activities that would be expected to contribute P to streams.

The median TP concentration of 250 U.S. Geological Survey (USGS) stream monitoring stations throughout the United States reported by Alexander and Smith (2006) was 0.12 mg/L. One-fourth of the sites had TP concentration above 0.25 mg/L and 10% were above 0.46 mg/L (Alexander and Smith 2006).

The USGS, in cooperation with the Oklahoma Water Resources Board (Haggard et al. 2003a) reported nutrient concentrations at 563 stream sites in Oklahoma and 4 sites in Arkansas to facilitate development of nutrient criteria for Oklahoma. The median and 75th percentile total P concentrations for larger streams (stream orders 4 and above) were 0.106 and 0.178 mg/L, respectively. For smaller streams (stream order 1 through 3), the median value ranged from 0.026 to 0.060 mg/L, depending on stream slope (steep streams had lower total P), and the 75th percentile values ranged from 0.05 (steep streams) to 0.110 mg/L (low gradient streams).

I analyzed the total P data in Dr. Olsen's Illinois Master Database under what Dr. Olsen classified as base flow and under all flow conditions. His base flow median and 75th percentile total P concentrations (1,071 samples) were 0.055 and 0.121 mg/L, respectively. Corresponding values under all flow conditions (1,527 samples) were 0.062 and 0.142 mg/L, respectively. These values are similar to results obtained in the other surveys discussed above.

Thus, we can put into context the median total P concentrations in IRW streams reported by Plaintiffs' consultant, Dr. Stevenson (2008) that ranged from 0.057 to 0.076 mg/L depending on the year and season, and the TP concentration at all sampling stations, as represented in Dr. Olsen's stream database for this case (median TP equal to 0.062 mg/L). While these concentrations are indeed above the 0.037 mg/L standard for designated Scenic Rivers in the IRW, they are not unusual in comparison with values reported elsewhere by the U.S. EPA and USGS. The IRW streams sampled by Plaintiffs' consultants in this case were not unusual with respect to their total P concentrations, compared with streams elsewhere in Oklahoma, the surrounding region, or the nation.

The median fecal coliform bacteria concentration for the 250 USGS stream monitoring stations was 329 cfu/100 ml. Twenty-five percent of the sites had FCB above 950 cfu/100 ml and 10% were above 2,345 cfu/100 ml (Alexander and Smith 2006). In comparison, based on Dr. Olsen's database, the median FCB concentration for streams in the IRW was 130 cfu/100 ml. Twenty-five percent of the IRW stream samples had FCB higher than 810 cfu/100 ml and 10% of the samples had FCB higher than 4,600 cfu/100 ml. Furthermore, the median watershed in the USGS study reported by Alexander and Smith (2006) may have been less impacted by human activities than is the IRW. For example, the median population density was only 14 people per square kilometer, compared with 70 people per square kilometer in the IRW. Despite the lower density of people in the median USGS watershed, it nevertheless had higher FCB concentration than the median IRW stream.

Whereas I do not necessarily accept Plaintiffs' classification of the Illinois River as eutrophic (see Connolly 2008) , many streams around the United States are considered to be eutrophic. For example, Alexander and Smith (2006) reported statistics for the 250 nationally representative riverine monitoring stations surveyed by USGS throughout the United States. About half of all sites nationwide, and about 60% of all sites situated in predominantly agricultural or urban watersheds, were classified as eutrophic in 1994 on the basis of measured TP concentrations. Alexander and Smith (2006) estimated water quality parameters standardized for stream flow and seasonal variability. Each of the stations had at least 70 records of TP; data were collected between 1973 and 1994 at sites that generally had watershed areas larger than about 1,000 km^2. They found that the median concentration of TP was 0.12 mg/L Thus, for both TP and fecal coliform bacteria, the median concentration in the IRW, based on Dr. Olsen's data collected under all flow conditions, were above some water quality standards, but nevertheless were about half as high as the median values reported by USGS for the 250 nationally representative riverine monitoring stations.

Based on results of analyses summarized above, compared with streams and reservoirs sampled in many studies throughout Oklahoma, the region of the IRW, and the United States as a whole, in a number of large surveys, neither the concentrations of TP nor fecal coliform bacteria in the IRW are unusual.

3. Water quality data in the IRW reflect a variety of sources associated with a mix of land uses.

The land area of the Illinois River watershed is a complex patchwork of urban, rural residential, agricultural, and forest land uses (Figure 3-1), with a variety of potential P and fecal indicator bacteria sources to stream water. Land application of poultry litter is only one among many potential sources. The most important sources of P to stream water are probably waste water treatment plant effluent, livestock, septic systems, erosion, and runoff from urban and other developed areas. The most important sources of fecal indicator bacteria are probably livestock, septic systems, urban runoff, accidental sewage discharge and other sewage bypasses, river recreationists, and wildlife. All of these sources contribute P and/or fecal indicator bacteria to stream water, dependent upon location, rainfall, flow conditions, human and animal populations, and variations in land use. Most of these sources were ignored or unreasonably dismissed as unimportant by the Plaintiffs' consultants in this case.

Because the land uses within the watershed are so patchy (see Figure 3-1) and because so much of the urban land use (a major source area of both P and fecal indicator bacteria to streams) is located in the headwater regions of the watershed, it may be impossible to discriminate precisely among the various nonpoint P and bacteria sources based on observed geographic patterns in P or bacterial concentration. Certainly the Plaintiffs' consultants did not design and implement a sampling program that discriminated among the various potentially important sources of NPS pollutants.

Headwaters are important in this assessment because stream flows in headwater areas are lower than further down the stream system, and therefore inputs of P and bacteria have larger influence on concentrations in stream water in the smaller headwater streams. Furthermore, contamination of streams with waste water treatment plant effluent and urban runoff in the headwater areas makes it difficult to evaluate the importance of multiple potential nonpoint sources of P and/or fecal indicator bacteria in agricultural and rural residential lands further downstream. Thus, streams in this watershed have concentrations of P and fecal indicator bacteria above water quality standards in the upper reaches of many of these stream systems, well above the mainstem Illinois River. The relative importance of each source is not known. These potential sources of P and bacteria cannot be ignored in any serious attempt to evaluate the possible causes of concentrations above standards at some locations in the IRW. There is no justification for singling out the poultry industry as the cause of P or fecal indicator bacteria above water quality standards in this watershed, especially given the large populations of people (on both sewered and septic waste water treatment) and cattle in the IRW. In addition, because of differences in the timing of improved land and facilities management, WWTP construction projects, and continued growth in the IRW, spatial patterns may be further obscured.

It is well known that the land uses that are common in the IRW are often associated with contributions of nutrients such as P and fecal indicator bacteria to streams. It is also well known that it is very difficult to quantify the relative contributions from the various source types. EPA (2002, page 14) stated the following:

> ***Detecting and ranking sources of pollutants** (to streams) **can require monitoring pollutant movement from numerous potential sources, such as failing septic systems, agricultural fields, urban runoff, municipal sewage treatment plants, and local waterfowl populations. Often, states are not able to determine the particular source responsible for impairment.***

In the IRW, Plaintiffs have not conducted the monitoring identified by EPA (2002) as required to determine the particular source(s) responsible for impairment of the streams in the watershed with respect to existing water quality standards for total P and fecal indicator bacteria. However, Plaintiffs' water quality data do allow a general assessment of source areas of P and fecal indicator bacteria; concentrations of these constituents tend to be highest downstream from urban areas and WWTP facilities (see discussion in Section III.5).

Land use in the IRW includes a large amount of agricultural land, most of which is used for pasture and hay production. Urban lands also occur, and are mainly found in the upper reaches of the watershed, in the headwater areas of the Illinois River and several of its tributary streams. It is well known that watersheds having agricultural and urban land use are more likely to receive inputs of nutrients to streams and to have their drainage waters classified as eutrophic than are watersheds having forested land use (Alexander and Smith 2006).

4. *There are large numbers of people and their animals in the IRW, and Plaintiffs' consultants did not fully consider their importance as potential sources of nutrients and fecal indicator bacteria to stream waters within the watershed. Plaintiffs' consultants also did not fully consider the importance of the rapid increase in the human population that has occurred within the IRW in recent decades.*

<u>Current and Recent Population Estimates</u>

Plaintiffs' consultants largely ignored the substantial current human and cattle populations in the IRW and the extent to which the human population has been increasing in recent years, with concomitant increased potential for NPS contributions to streams.

Based on the U.S. Census, there were about 237,000 people in the IRW in the year 2000, of which approximately 160,500 lived in sewered communities, and 76,500 lived in rural areas, presumably on septic systems (Table 4-1). Such a large number of people would be expected to contribute NPS pollutants to stream waters within the watershed regardless of whether or not poultry litter had been land-applied. Pollutant sources would be expected to include bacteria and nutrients contributed via human waste (for example, from waste water treatment plant effluent, septic system drainage, leaking sewer pipes, accidental bypasses of raw sewage, land application of biosolids) and via pet waste. In addition, P can be contributed from soaps and other household products, lawn and garden fertilizer, and urban runoff from impervious surfaces (roofs, roads, sidewalks, parking lots, etc); such runoff would include nutrients and bacteria from fertilizers and animals such as birds, deer, and other wildlife, as well as pets. Roads (especially dirt roads), culverts, and stream banks from which soil-holding trees and other plants have been removed are well-known sources of erosion. Erosion includes the movement (via water, gravity, and/or wind) of soil from the land surface to a stream. It preferentially involves movement of the smaller soil particles (especially clay size particles), and erosion can carry a substantial amount of P adsorbed to soil particles.

I estimate, using American Veterinary Medicine Association estimates for 2001 of 1.7 dogs and 2.2 cats per household in the United States (http://www.avma.org/reference/marketstats/ownership.asp) together with the U.S. Census estimate of 2.67 people per household (http://www.petpopulation.org/faq.html) and the human population estimates given in Table 4-2, that there are over 189,000 dogs and 244,000 cats in the IRW. This assumes that these national estimates are applicable to the IRW, so there is some uncertainty in these estimates. Regardless, it is clear that there are large numbers of dogs and cats in the watershed. It is also obvious that these pets are especially numerous in the upper reaches of the watershed where most of the people live. Pet waste constitutes an important potential source of fecal indicator bacteria and P to urban runoff.

It is noteworthy that developed areas, which include most of the people and therefore many of the pets that reside within the watershed, also contain relatively high percentages of impervious land, from which contaminants from pets, fertilizer application, erosion, and other sources can move rapidly and efficiently to streams. This pollutant transport pathway is accentuated by storm drains, gutters, and roadside ditches that are constructed in urban areas in order to facilitate efficient movement of water into streams during rainstorms. Such water routing infrastructure is an important tool for reducing flooding in urban areas. However, it also provides an efficient conduit for transporting contaminants from the urban landscape to streams. Waste from urban wildlife, including deer, rodents, and birds, as well as cats and dogs, can further add to the flux of contaminants to streams in the urban areas.

Defendants' expert, Dr. Clay (2008), estimated that there are approximately 199,000 cattle, 166,000 swine, 8,000 horses, and 2,000 sheep present in the watershed. Cattle, in particular, have access to streams and streamside (riparian) areas throughout the watershed. Cattle tend to spend a disproportionate amount of their time in and adjacent to streams because such areas provide a source of water, often a source of shade, and an opportunity for cooling during summer months (Clay 2008).

Plaintiffs' consultants contend that cattle do not contribute P to the IRW because they merely recycle the P that is already present in the forage that they consume. This contention reflects a complete misunderstanding of NPS pollutant transport processes. As discussed in Section III.17 of this report, the mere presence of P within the watershed reveals nothing about the propensity of that P to move into a stream; one must also consider the transport opportunities and pathways. Similarly, one cannot ignore the importance of cattle-mediated transport of P from the location of forage ingestion in a pasture directly to the stream or to the riparian area adjacent to the stream. This is critically important because P is typically not readily transported from pasture to stream. Rainfall on much of the surface of a pasture tends to infiltrate into the soil where the P can become adsorbed, rather than running off the surface as overland flow (see discussion in Section III.7 of this report). In contrast, cattle that have free access to streams can directly deposit their feces (with its P and bacteria content) into a stream or to the adjacent riparian land that may be hydrologically active, from which transport to the stream can readily occur during a rainstorm. Thus, the actions of cattle, consuming forage throughout the pasture and then preferentially depositing their feces in or near the stream, constitute an important source contributing P and fecal indicator bacteria to streams in the IRW that was largely ignored by Plaintiffs' consultants.

It is largely because cattle can represent a major NPS pollutant transport mechanism in pasture settings that agricultural best management practices (BMPs) commonly entail construction of fences (with associated off-stream watering systems) to keep cattle out of riparian zones and streams. Intended benefits of riparian fencing include reduced contamination of stream water with livestock feces and its associated nutrient and bacteria content, reduced trampling of riparian vegetation, and reduced stream bank and riparian erosion. Riparian fencing resource protection actions occur nationwide, in many cases funded by the federal government.

It is well-recognized that cattle pose an important source of NPS pollution to streams. In fact, Total Maximum Daily Load (TMDL) analyses in watersheds throughout much of Oklahoma typically conclude that cattle constitute the principal source of fecal indicator bacteria to streams (See discussion of this issue in Section III.6 of this report). Nevertheless, Plaintiffs' consultants largely ignored or dismissed the importance of cattle in the IRW, despite the large numbers of cattle present and the wide prevalence of their access to streams within the watershed.

Plaintiffs' consultants also failed to fully address the fact that feces from an estimated 170,000 swine that live in the IRW are commonly land applied. Waste water treatment biosolids have also been land applied (Jarman 2008). Plaintiffs' consultants did not appropriately address these potential sources of contaminants to stream water, but instead focus on poultry litter, nearly to the exclusion of other known and suspected sources of P and fecal indicator bacteria.

<u>Change in Populations Over Time</u>

The human population in the IRW has been increasing dramatically for the past several decades. Between 1990 and 2007, it increased by about 77% (Table 4-2). In fact, northwest Arkansas has been one of the fastest growing metropolitan areas in the United States in recent years. The total human population in the watershed has increased from about 168,000 people in 1990 to about 297,000 people in 2007 (Table 4-2).The estimated total human population in the IRW increased by over 40% just within the decade of the 1990s. Much of this increase has occurred in the headwater areas of the IRW in the northeastern portions of the watershed. Changes over just a seven year period of time are mapped in Figure 4-1. Human population increases have been especially pronounced in the upper (easternmost) part of the watershed.

Along with the large increase in human population has been a large amount of construction: of housing, shopping centers, and other human infrastructure. Construction activities and urban development are especially widespread throughout the headwater portion of the watershed. For example, Grip (2008) mapped, from examination of aerial photographs and existing maps, new land development in a study area between Rogers and Fayetteville, within the IRW. The study area comprised 152 square miles. Mr. Grip obtained aerial photographs that covered the study area, corresponding to four time periods: 1976-1982, 1994-1995, 2001, and 2006. Developed areas that involved residential and commercial development were identified and mapped, excluding any development that was focused on golf courses, parkland, forestry, crops or pasture. During the initial time period examined (1976-1982), 12.6% of the study area was classified as developed. By 1994-1995, this increased to 22.4%; by 2001, it increased to 29.4%. The cumulative development by 2006 had increased to 39.3%, more than three times the amount of developed land in the earliest period examined (approximately 24 to 30 years previously).

With construction and urban development, there is a substantial increase in the amount of impervious land surface (pavement, roofs, parking lots, compacted soils, etc). Runoff during rainstorms from these impervious areas is largely not directed down through soils (which could remove bacteria from the drainage water), but rather flows overland and through storm drains, providing direct conduits for bacterial and nutrient transport from the ground surface to stream water. Thus, eroded sediment and also bacteria and P deposited on the ground surface by pets, hobby farm livestock, or wild mammals and birds can be efficiently transported from such areas to streams. For this reason, urban areas and developed areas commonly constitute important sources of NPS pollutants to streams. Plaintiffs' consultants have ignored the rapid increase in the human population within the watershed, along with the concomitant large increase in such potential sources of stream pollution.

5. Effluent and drainage water from urban areas in general, and municipal waste water treatment plants in particular, are major sources of P to surface waters in the IRW.

Urbanization is well-known as a major source of NPS pollution in the United States (Dillon and Kirchner 1975, Novotny 1995). Nevertheless, it was not fully considered by Plaintiffs' consultants in this case. Other than providing a limited and incomplete evaluation of waste water treatment effluent sources to streams and deleting watersheds having urban land use from some analyses, aspects of urban contribution of NPS pollution were generally not investigated by Plaintiffs' consultants.

My analyses show that spatial patterns in measured total P concentrations in stream waters of the IRW indicate an association with urban land use, and especially with the location of WWTP effluent discharge. Analyses conducted and reported by Defendants' expert Dr. Connolly (2008) further support this conclusion. As described below, highest values of stream total P concentration tend to be located downstream of urban land use and especially downstream of WWTP effluent sources to the streams. Plaintiffs' own data show that the sites that exhibit the highest concentration of total P, expressed as the geomean of five or more samples at a given location, are immediately downstream of the locations of WWTPs, sewage lagoons and/or urban areas.

Plaintiffs' consultants ignored or failed to recognize that stream water P concentrations in the IRW tend to be highest immediately downstream of urban pollution sources. Their analyses were directed towards portions of the watershed assumed to receive land application of poultry litter, and they failed to fully consider the presence of other potential sources of the same constituents that they claimed were contributed to streams from poultry litter application.

As an example, Plaintiffs' consultants collected paired stream samples above and below three waste water treatment plant effluent discharge locations. The resulting total P data are depicted in Figure 5-1, showing that the concentrations of total P in the streams were generally below the 0.037 mg/L standard at the locations above the WWTPs, but substantially higher immediately downstream from the WWTPs. Plaintiffs' consultants did not report such observations in their various reports for this case.

Similarly, an analysis of data collected by Plaintiffs' consultants at variable distances downstream from several WWTP locations (shown in Figure 5-2) illustrate that concentrations of total P in stream water tend to be highest immediately downstream of the location of the WWTP effluent discharge point, and subsequently decrease further downstream **(**Figure 5-3). Similar results were found by Haggard et al. (2001) in an investigation of the effects of the Columbia Hollow WWTP on Spavinaw Creek, Arkansas; they found a marked increase (about 8 to 25 times higher) in soluble reactive P in the stream immediately below the point of WWTP discharge compared with above the discharge, with a gradual decline in the P concentration in the downstream direction below the WWTP. The concentration of P in stream water decreases gradually in a downstream direction from the WWTPs in part because P settles to the stream sediment. The P that accumulates in the sediment can later be remobilized by high stream flows or in response to changing equilibrium conditions between the stream water and the sediment. Haggard et al. (2001) further concluded that the nutrient retention capacity of the stream was greatly reduced as a consequence of the point source. They concluded that:

> ***PS [**point source**] inputs diminish the ability of the stream to withstand other anthropogenic nutrient inputs***

All of these spatial patterns observed in the Plaintiffs' database illustrate the strong association between WWTP effluent (and also urban land use in general) and the occurrence of relatively high concentrations of total P in streams in the IRW. These patterns suggest that the largest sources of P to streams in the IRW are likely associated with urban development. This finding is not new or surprising. As discussed more fully below, urban development is commonly associated with both point and nonpoint source pollution of streams. There is a great deal of urban development in the IRW, and much of that development is recent. Nevertheless, Plaintiffs' consultants generally chose to focus on a presumed linkage with land application of poultry litter, almost to the exclusion of other sources, including the urban sources that their own data implicate as critically important in this watershed.

The finding that stream P concentrations in the IRW are strongly associated with waste water treatment effluent discharge is not new. The Arkansas Department of Pollution Control and Ecology, Water Division (ADPCE 1995) reported results of a study on water quality and biological response in Sager Creek in response to the effects of waste water discharge into the creek from the City of Siloam Springs. Stream samples were collected between July 1993 and June 1994 above and below the point of Siloam Springs waste water treatment plant effluent discharge into Sager Creek. The work was done in response to objections by the State of Oklahoma to proposed discharge permit modifications. Water quality samples were collected and analyzed for total P (and other parameters) approximately once every two months during the one-year study. Two sample sites bracketed the waste water treatment plant: site SAG07 was located 500 ft above the outfall, and site SAG09 was located 500 ft below the outfall. The median (of six samples) total P concentration was 0.06 mg/L at site SAG07, which increased dramatically to 1.38 mg/L at site SAG09, presumably due to the influence of the effluent contribution to the stream. In addition, samples were collected during a low-flow period on June 28, 1994 and during a high-flow event on November 16, 1993. During both flow regimes, stream concentrations of total P were relatively low upstream from the treatment plant, but dramatically higher (especially during low flow conditions) at the site (SAG09) immediately downstream from the waste water discharge (Figure 5-4). During high flow conditions, the concentration of total P increased by more than a factor of 1.5 from immediately above to immediately below the WWTP; during low flow, the difference was more than a factor of 20.

Haggard et al. (2004) reported soluble reactive P (SRP) concentrations immediately downstream of WWTPs on Spring Creek and Sager Creek in the IRW in July 2002. Concentrations of SRP in stream water below the respective WWTP exceeded 1.5 mg/L in Sager Creek and 6 mg/L in Spring Creek; these concentrations were more than an order of magnitude higher than at the sampling locations above the WWTPs and more than an order of magnitude higher than the water quality standard for Scenic Rivers in Oklahoma. Haggard et al. (2004) concluded, based on their study and also numerous other literature citations that:

> ***Phosphorus concentrations in streams generally show a sequential decrease with increasing distance from municipal WWTP effluent discharge.***

Thus, the importance of WWTPs to stream P concentrations in the IRW and elsewhere is not new information. This has been well known for a long time (See studies cited by Ekka et al. (2006) and study by Haggard et al.(2003). Ekka et al. (2006) published an in-depth study of waste water P contributions to streams and stream chemistry in 2002 and 2003 from the cities of Fayetteville, Rogers, Springdale, and Siloam Springs in NW Arkansas. Effluent discharge significantly altered water chemistry, including P concentration, in Mud Creek, Osage Creek, Sager and Flint Creeks, and Spring Creek. These are all tributaries to the Illinois River within the IRW. Mean discharge (stream flow) downstream from the effluent inputs increased from 2 to 57 times compared with the discharge measured upstream of the WWTPs. This illustrates that these headwater streams are effluent dominated. The Fayetteville and Rogers WWTPs discharged water with average total P concentrations of 0.25 and 0.35 mg/L during the study period into Mud and Osage Creeks, respectively. The Springdale WWTP discharged an average effluent TP concentration of 4.4 mg/L into Spring Creek. Average effluent P concentration was not available from the Siloam Springs facility, but it appeared that the change in dissolved P concentration in Sager and Flint Creeks was somewhere between those of Spring Creek and Mud or Osage Creeks (Ekka, 2006). Results from this study showed that stream SRP concentrations increased several fold downstream from effluent inputs (Table 5-1). The most profound effect of WWTP effluent on stream P values was in Spring Creek, which had the highest SRP concentration measured in the study (7.0 mg/L in August 2002). This is more than 189 times higher than the 0.037 water quality standard that is applicable to the main stem rivers in this watershed. Ekka et al. (2006) concluded from his study of streams in the IRW that:

> ***point sources such as municipal waste water treatment plant (WWTP) effluent discharges still exert a prominent influence on dissolved phosphorus (P) concentrations and transport in Ozark streams, particularly in northwest Arkansas, USA (***several cited references***)***

Effluent discharges increase the concentration of P in the water column, and also increase P in the stream sediment (Ekka et al. 2006 and numerous other citations provided by Ekka et al. 2006). As a consequence, Ekka et al. (2006) concluded that:

> ***The influence of WWTP effluent discharge on benthic sediments is generally much greater than other external factors, such as agricultural land use and nonpoint source pollution in the Ozarks (Popova et al. 2006).***

The ability of stream sediments to adsorb P is often much less downstream from effluent discharge points, compared with locations upstream (Ekka, 2006). This can cause P concentrations in stream water to be higher, in response to inputs from any source, as a consequence of the P contributed to the stream sediments from the effluent discharge.

Haggard et al. (2003c) sampled 30 stream sites in the IRW from 1997 to 2001, including sampling sites on the main stem Illinois River, Clear/Mud Creeks, Osage Creek, and Spring Creek. They concluded that:

> ***The spatial distribution of these sites clearly identified elevated P concentrations at the Illinois River at Highway 59*** *[near the Arkansas/ Oklahoma border]* ***were likely from a single WWTP*** *[Springdale]* ***over 46 kilometers upstream… Over 35% of the P transported during surface runoff conditions was likely from resuspension of P retained by stream sediments. Thus, these sediments may represent a considerable transient storage pool of P after management strategies are utilized to reduce elevated P concentrations at the Illinois River.***

Dr. Olsen claimed, based on his principal components analysis (PCA), that samples for which his first principal component (PC1) was equal to or above his designated cutoff value of 1.3 exhibited what he identified as a unique poultry waste signature. Yet his own data show that base flow stream sites having PC1 above 1.3 are largely located immediately downstream of urban areas and WWTPs (Glenn Johnson 2008, his Figure 3-16). Based on this observed spatial pattern, Dr. Glenn Johnson (2008, page 56) concluded:

> ***Whatever is driving PC1 … it is in large part coming from areas of high human population, in absence of poultry***

Defendants' expert, Dr. Jarman (2008) documented contributions of P and fecal indicator bacteria to the IRW as permitted discharges from WWTPs, accidental bypasses/overflow releases, and land application of biosolids. He also provided data illustrating a poor history of responsiveness by Oklahoma regulatory agencies in dealing with violations by point sources which caused contributions of these constituents to surface waters in the IRW. The importance of point source contributions of nutrients to streams in the IRW have been well recognized at least since the 1980s (Jarman, December 2008). Plaintiffs' consultants have under-emphasized the continued importance of point source contribution in this watershed, by failing to recognize the clear association of P concentrations in streams within the watershed with locations of WWTPs, selectively deleting (without properly clarifying the effects of this action on key conclusions) from some of their analyses sites that were downstream from WWTPs (Dr. Engel, 2008), and choosing a human per capita P production rate at the lower end of available estimates (Ms. Smith and Dr. Engel, as per Figure 8 in Jarman, 2008).

Phosphorus concentrations in WWTP effluent were higher in the past than they are currently because of more recent P limitations placed on effluent and because of the elimination of phosphate laundry detergent. The manufacture of phosphate detergent for household laundry was ended voluntarily by the industry in about 1994 after many states, including Arkansas, had established state-wide phosphate detergent bans (Litke, 1999). After WW II, powdered clothes washing detergents were about 15% P by weight. In 1970, the industry limited the P content to 8.7% by weight in response to national concerns about eutrophication. In 1971, five cities in Illinois limited P-containing laundry detergents. The number of states having phosphate detergent bans increased steadily after 1971, up to 26 states by 1995. During the 1940s, the total P concentrations in raw household waste water effluent averaged about 3 mg/L, increasing to about 11 mg/L at the height of phosphate detergent use about 1970, and have since declined to about 5 mg/L (Litke, 1999).

Although substantial progress has been made in reducing point source contributions of P to streams in the IRW, it is likely that many of the improvements are only recently having an influence on water quality. In the mid-1990s, Arkansas and Oklahoma state agencies and cities agreed to consider methods to reduce P inputs by 40%, and P limitations were placed on WWTPs in the IRW (Jarman, December, 2008). However, for most treatment plants, these changes were not fully implemented until about 2003, and some still do not have discharge limitations (Jarman, December 2008). Therefore, the influence of these point source reductions may not be evident in much of the available water quality data for this watershed, especially the data collected prior to about 2003. Defendants' expert, Dr. Jarman reported approximately a 40% decline in P contribution in WWTP effluent in the IRW between the period 1997 -2003 and the period 2004-2007. This decrease corresponded with approximately a 40% decline in the concentration of P in base flow stream water in the Illinois River at Tahlequah, near the upper end of Lake Tenkiller (Connolly 2008).

Despite these substantial improvements in P contribution from WWTP point sources to streams in the IRW, even for the WWTPs that do now have more stringent P limitations, these limitations of 1 or 2 mg/L of TP in the effluent are still 27 to 54 times higher than the 0.037 mg/L standard for the Scenic River sections of the stream system in the IRW.

Nelson et al. (2003) estimated P loads and concentrations in the Illinois River at the Highway 59 bridge crossing in Arkansas, near the Oklahoma state line, and compared them with loads and concentrations estimated for five other streams. They found that their estimates of base flow concentrations of total P for five of the six watersheds (all except Moores Creek) were similar (near 0.25 mg/L), and stated:

> ***This is a possible confirmation that the base- flow concentrations are effected by wastewater treatment plant discharges, as Moores Creek is the only watershed without a permitted WWTP discharge.***

The WWTPs in Springdale, Fayetteville, Siloam Springs and Rogers have all agreed to reduce effluent total P concentrations to less than 1 mg/L (Ekka et al. 2006). Nevertheless, this voluntary reduction, if fully implemented, will still allow effluent discharged from these facilities into IRW streams to contain total P that is 27 times higher than the 0.037 mg/L standard.

WWTPs are not the only potential municipal sewage point sources of nutrients and fecal indicator bacteria to streams within the IRW. Jarman (2008) documented problems associated with the Watts total retention (lagoon) waste water treatment facility, which is situated within a quarter of a mile of the main stem Illinois River in Oklahoma, adjacent to the Arkansas state line. Although there is no effluent discharge from this sewage treatment facility, there is still the risk of pollution contributions to the river due to land application of treated sewage. The land application area associated with this facility is located within about 100 feet of the river. The U.S. Fish and Wildlife Service (USFWS) expressed concerns over a proposal for the Watts facility to begin taking waste water from the city of West Siloam Springs. The USFWS concern centered on application of treated waste water to hydric soils in the flood plain of the Illinois River. Jarman (2008) reported an accidental release of 275,000 gallons of treated waste water from the facility in 1999, which resulted in assessment of a $20,000 penalty by ODEQ. An assessment prior to this accidental release by Enercon Services, Inc, in a study commissioned by the Oklahoma Attorney General and the OSRC, concluded that:

> ***its proximity to the River and the presence of numerous pathways virtually assures that the Illinois River will be the target of and ultimate recipient of the contaminants associated with the Watts lagoon. (**cited in Jarman 2008**)***

It is important to note that, even though municipal sewage treatment facilities, such as WWTPs and the Watts lagoon, constitute an overwhelmingly important source of nutrients to stream water, they are not the only important sources of NPS water pollution associated with urban development. Runoff from urban areas also is well known to contribute substantial amounts of fecal indicator bacteria, nutrients, sediment, and other constituents to drainage water. Urban sources of these constituents can include fertilizer use on lawns and parks, pet and urban wildlife waste, erosion associated with construction activities, and broken or leaking sewer pipes.

Urban areas contain relatively high proportions of impervious land (i.e., parking lots, compacted soils on construction sites, roofs, roads, sidewalks, etc.), from which contaminants of all kinds can be rapidly flushed to streams during rain storms. Urban areas are specifically designed so as to move rain water quickly and efficiently to streams in order to prevent flooding. This is typically done via installation of extensive systems of storm drains, gutters, and roadside ditches. An unfortunate effect of such rapid routing of runoff into streams within urban areas is that there is much less opportunity for constituents such as P and fecal indicator bacteria, which tend to be removed from infiltrating water and retained on soils, to be removed from the runoff before it enters a stream. In urban areas, less water is routed through soils; more water is routed overland. As a consequence, proportionately more P and bacteria are carried from the land into the stream. This concept is not new; it is not specific to the IRW. Rather, it is a well-known facet of NPS pollution science. It was ignored by the Plaintiffs' consultants in this case.

Novotny (1995, page 23) concluded that urbanization is probably the greatest source of NPS pollution to streams. Nevertheless, it was not considered by Plaintiffs' consultants in targeting their sampling or interpreting much of their resulting data. Urbanization changes the hydrology of the watershed to favor transport of pollutants from the land surface to streams. Lawn fertilizers, pet waste, and urban wildlife waste are flushed into storm drains, bypassing the soils that might otherwise adsorb some of the contaminants present in that water. Soil loss to erosion from construction sites can reach magnitudes of over 100 tons per hectare per year. For that reason, construction occurring in only a small percentage of the watershed can contribute a major portion of the sediment carried by streams in the watershed (Novotny 1995, page 25). This sediment contributes directly to elevated suspended solids and turbidity; it also carries P. Novotny (1995, page 24) cautioned that newly developing urban lands (which are very common in the IRW) should receive special attention in NPS assessment:

> ***this stage of land is characterized by the high production of suspended solids caused by erosion of unprotected exposed soil and soil piles…Extremely high pollutant loads are produced from construction sites if no erosion control practices are implemented. Therefore, in establishing pollutant loadings relative to land uses, one must determine first whether the area is fully developed or if it is a developing area and/or significant construction activities are taking place therein.***

Novotny's caution is especially relevant to NPS pollution in the IRW. As described in Section III.3 of this report and by Grip (2008), new construction is widespread in the IRW, and northwest Arkansas has been in recent years one of the fastest growing metropolitan areas in the United States.

With an increase in the amount of impervious surfaces in response to urbanization, the urban portions of the watershed become more hydrologically active. Runoff events carrying heavy pollutant loads become more common (Novotny, 1995, page 27). Pollutants that accumulate in the streets, parking lots, and areas of compressed soil are readily transported in surface runoff. These pollutants can include dust and soil particles (which can be high in P content), animal waste, atmospherically deposited nutrients, and fertilizers. High-density urban zones are nearly completely impervious and have very limited capacity to attenuate pollution, with almost all emitted pollutants eventually reaching surface waters (Novotny and Olem 1994, page 493). Novotny (1995, page 45), based on EPA's Nationwide Urban Runoff Project (NURP), estimated that the event mean concentration of TP in urban runoff for the median urban site was 0.37 to 0.47 mg/L, with the 90th percentile urban site yielding an event mean concentration of TP equal to 0.78 to 0.99 mg/L. The TP in urban runoff would be expected to be partly from erosion and partly from other P contributions associated with such factors as fertilizer use, pet waste, leaking or faulty sewer lines, urban wildlife, and other sources.

Data from EPA's National Urban Runoff Program (U.S. EPA, 1983) found that the median urban stream site in the United States received storm runoff having total P concentration of 0.37 (10 times higher than the Illinois River standard) to 0.47 mg/L, with 10% of values more than twice as high (Novotny 1995, page 61). EPA (1983) further concluded that:

> ***Fecal coliform counts in urban runoff are typically in the tens to hundreds of thousand per 100 ml during warm weather conditions, with the median for all sites being around 21,000/100ml.***

For comparison, the median concentration of fecal coliform bacteria in streams sampled in the IRW by Plaintiffs' consultants in areas representing a variety of land uses and reported in Dr. Olsen's database was 130 cfu/100 ml.

It has been previously shown that nutrient exports from urban watersheds can be as high, or higher, than exports from agricultural lands. For example Osborne and Wiley (1988) investigated land use and stream water quality in the Salt Fork watershed in Illinois, which is primarily (90%) agricultural. Urban areas accounted for 5% of the total watershed areas, which (as in the IRW) was concentrated in the upper watershed. They found that:

> ***Despite the over-riding dominance of agricultural land use within the Salt Fork watershed, our results demonstrate that urbanization rather than agriculture has the greatest impact on stream SRP concentrations.***

The Illinois River Management Plan (OSRC, OSU, and NPS, 1999) concluded that:

> ***Urban runoff is recognized as one of the major non-point sources of pollutants within watersheds. The Illinois River Corridor is a mixture of moderately populated urban areas with a large growing suburban and rural population.***

Urban land use has also been associated with negative impacts on stream biological integrity. For example, Wang et al. (1997) found that urban impacts on stream biological integrity in Wisconsin became severe when the percent of the watershed covered by urban land use exceeded 10% to 20%. Effects have been associated with the amount of impervious surface area, amount of developed land, and population density (Klein 1979, Benke et al. 1981, Jones and Clark 1987, Lenat and Crawford 1994).

Parsons and University of Arkansas (2004) characterized water quality and aquatic biological resources of several streams in the IRW. The objective was to provide data to U.S. EPA for use in evaluating potential 303(d) listings of water quality impairment for Arkansas. They concluded that multiple stressors are affecting this system at all times. Water chemistry nutrient results at locations downstream from WWTPs were nearly always higher in nutrient concentrations than the respective upstream location. Of the 12 sites assessed in the IRW for this study, one was classified as “severely impacted” and two were classified as “impacted” on the basis of multiple chemical and biological indicators of environmental health. The severely impacted site was located on Spring Creek below the Springdale WWTP. One of the impacted sites was located on Muddy Fork below the Prairie Grove WWTP. The other impacted site was located on Osage Creek, below urban development and multiple WWTP discharge locations.

According to data compiled for this case by Defendants’ expert, Dr. Ron Jarman, WWTP effluent within the IRW usually contains about 10 to 40 cfu/100 ml, on average, of FCB. Nevertheless, effluent discharged directly into the Illinois River system sometimes contains levels that exceed the 200 cfu/100 ml Primary Body Contact Recreation standard, including values in the thousands of cfu per 100 ml. Such values of bacteria in the effluent from WWTPs contribute to the overall bacterial concentrations in the streams within the watershed.

Routine operation of WWTP facilities contributes well known point sources of P and fecal indicator bacteria. In addition to these routine contributions, there are numerous accidental releases of these constituents to the stream system. The accidental release of raw or partially treated sewage is not an unusual event in the collection system of a WWTP. This can introduce large amounts of nutrients and fecal indicator bacteria to stream waters. Jarman (2008) noted that there are many causes for these events, including line breakage, blocking or plugging of the lines, construction damage, heavy rainfall, and system breakdowns at a lift station or the WWTP. Such events represent a recurring source of nutrients and fecal bacteria in urban settings.

Dr. Jarman documented sewage bypasses (uncontrolled discharge of untreated or partially treated sewage) within the watershed over a period of seven years. Although data were not available from all townships within the watershed, and data were only available for some years in others, Dr. Jarman reported about 700 hours of sewage bypass with average concentrations of FCB in the range of 1.5×10^{15} (one and a half thousand trillion) or higher per bypass event (Table 5-2). Most of these bypasses involved raw sewage, in volumes that averaged 500 gallons (Westville) to 9,060 gallons (Lincoln). I have become aware of additional bypass data that were not included in Table 5-2, indicating two bypasses from the Stilwell facility comprised of 1 million and 800,000 gallons of raw sewage. These bypasses data were discussed by Dr. Madden in his September, 2008 deposition for this case (Madden 2008, deposition transcript, pages 61 to 71). Thus, sewage bypasses constitute an important additional source of fecal bacteria to stream water in this watershed.

Mixed land use watersheds often have mainly forests in the upper reaches, and urban and agricultural land uses in the lower reaches. Therefore, contaminants that might be contributed to the streams from humans and their activities and their livestock often increase in a downstream direction, from the headwaters to the larger streams that are found downstream. The IRW is fairly unusual in that urban development is concentrated mainly within the headwater areas of the watershed (See Figure 3-1). For that reason, stream waters in the IRW tend to have relatively high concentrations of P and fecal indicator bacteria even within the upper stream reaches. This makes it difficult to evaluate the relative importance of different sources of contaminants found in the non-urban areas in this watershed. The Comprehensive Basin Management Plan for the IRW (Haraughty 1999, page 30) correctly identified that:

> ***…much of the phosphorus comes from the headwaters of the watershed, thus remediation efforts should concentrate in this area.***

Stream water data collected by Plaintiffs' consultants for this case clearly show the dominant influence of urban areas in general, and WWTPs in particular, on stream total P concentrations and to a lesser extent stream *E. coli* concentrations. Figure 5-5 illustrates the spatial patterns in total P concentrations in the IRW during low flow conditions, based on the geomean of 5 or more samples calculated from Dr. Olsen's database. The same pattern is seen for Dr. Olsen's data when samples collected under all flow regimes are included (Figure 5-6).

The water quality standard for P in the IRW is frequently exceeded even under low flow conditions (Figure 5-5), at times when NPS pollution associated with activities on pasture lands would not be expected to contribute appreciably to stream water quality. Such exceedances of the P water quality standard during low flow are probably caused primarily by point sources of pollution, mainly waste water treatment plant discharge from municipalities, directly into streams within the watershed. All of the low flow geomean P values that were relatively high were based on samples collected downstream from a developed area and downstream from a WWTP.

Dr. Olsen's database contains fewer samples analyzed for *E. coli*, so for those maps the criterion was relaxed to include all sites for which there were at least three (rather than 5) samples on which to base the geomean calculation. Geomean *E. coli* results for base flow and for all flow conditions are shown in Figures 5-7 and 5-8, respectively. Although there are fewer sample locations that met the criterion for number of samples, the patterns are similar. Again, the highest geomean concentrations tend to be located downstream from urban areas and WWTPs.

Thus, with nearly 300,000 people living in the IRW, mostly in urban areas in the upper watershed, there are clearly substantial sources of fecal indicator bacteria and nutrients to streams that flow through these urban areas. Plaintiffs' own data show this. The scientific literature shows this. Attempts to place most of the blame on land application of poultry litter (or any other source in the non-urban portions of this watershed) simply makes no sense.

6. Within non-urban areas in the IRW, there are many potential sources of P and fecal indicator bacteria to stream waters.

In addition to urban sources of NPS pollutants to streams in the IRW, described above, there are also multiple potential sources of P and fecal indicator bacteria to stream waters within the non-urban portions of the watershed. Plaintiffs' consultants **assume** that poultry litter application is the only, or the dominant, source in non-urban areas. They do not adequately assess the importance of the other potential sources. These other potential sources include, in particular, cattle manure, septic systems, roads and associated ditches and culverts, and other livestock and wildlife. Plaintiffs' consultants largely ignore or dismiss these other well-known potential sources of NPS pollution.

Cattle Manure

Cattle grazing is well known to be an important source of NPS pollutants to streams (Clark et al. 1999). In view of the large number of cattle in the IRW (Clay 2008), the importance of cattle as contributors of P and fecal indicator bacteria to streams in the IRW must be evaluated in any credible assessment of NPS pollution. Plaintiffs' consultants did not perform such an evaluation. Rather, they assumed that cattle could not be major contributors to NPS pollution because cattle consume forage, which contains P, and then excrete it within the pasture system. Thus, Plaintiffs' consultants conclude that cattle do not bring new P into the watershed, and therefore that they cannot be responsible for transport of P and fecal indicator bacteria to the stream system. This line of reasoning is flawed because it totally ignores the importance of transport processes and the tendency of cattle to transfer, via their grazing and movement patterns and access to streams, P and fecal indicator bacteria from the upland pasture areas to the stream itself or to the riparian zone adjacent to the stream, from which these constituents can much more readily be transported to stream water during a rain storm. This process is more fully explained in Sections III.11 and III.9 of this report. There are approximately 200,000 cattle, calves and milk cows in the IRW, based on agricultural census data compiled and provided to me by Dr. Billy Clay (pers. comm. 2008). I have observed that these animals commonly have access to streams and stream banks in the IRW. Clearly, they defecate directly into surface water, or defecate on land immediately adjacent to surface water (Clay 2008). Thus, fecal matter from livestock is both directly deposited into streams and is deposited to riparian zones where it is highly susceptible to surface transport from land to stream during rainstorms. In contrast, fecal matter in poultry litter, when the litter is properly applied, is not deposited in, or in proximity to, surface water or in areas that are likely to generate saturated overland flow from the pasture surface to the stream.

Cattle are widely distributed throughout the IRW, although the densest concentrations occur in proximity to the urban areas in the upper reaches (eastern portion) of the watershed (Figure 6-1). Because these livestock are so numerous and widely distributed, and because they occur in and immediately adjacent to streams in some areas, they cannot be ignored in evaluating fecal indicator bacteria and nutrient source issues in this watershed. The failure of Plaintiffs' consultants to fully consider the potential effects of cattle on the concentrations of P and fecal indicator bacteria in streams represents a major flaw in their analyses of water quality in the IRW.

Livestock pastures are well known sources of NPS stream pollution. Dismissal by Plaintiffs' consultants of the importance of cattle to NPS issues in the IRW is not consistent with the position taken by the Illinois River Management Plan (OSRC, OSU, and NPS 1999). The Management Plan concluded that:

> ***Unconfined livestock in the Illinois River Corridor have directly affected stream and riparian habitats. Removal of vegetation, trampling of streambanks and wading in shallow streambed areas has led to bank instability, increased erosion and sedimentation, and alteration of habitat.***

Plaintiffs' consultant, Dr. Berton Fisher, did not evaluate the extent to which cattle serve as a transport mechanism for taking P that was contained in living pasture grass and transporting it into or near water courses, although he acknowledged that cattle:

> ***can assist in that process.*** (September 4, 2008 deposition testimony, page 450-451)

Often, it is not the grazing intensity on the land that determines the extent of stream water pollution associated with cattle; rather, it is the unrestricted access of cattle to water that has the major impact (Novotny, 1995, page 23). I have observed that cattle in the IRW commonly have access to streams, and that cattle access to streams appears to be more widespread on the smaller tributaries than it is along the main stem Illinois River.

It has been reported in the scientific literature that P concentrations in runoff from intensively managed dairy pasture can be as high as 7.36 mg/L (Nash and Murdoch 1997, cited in Haygarth and Jarvis 1999). Previous studies have found increased concentrations of nutrients in streams draining pasture land; for example, pasture in the Ozarks Highlands region of Missouri is associated with increased stream concentrations of nutrients, suspended solids and algal levels relative to forested areas (Perkins et al. 1998).

Cattle grazing in riparian areas can cause erosion and movement of P into stream waters. Butler et al. (2006) found that vegetative ground cover has a large impact on the volume of surface runoff and P export from pastured riparian areas. Riparian areas with bare ground contributed substantial amounts of sediment and P to surface waters during heavy rainfall.

Plaintiffs' consultant, Dr. Fisher, testified in his deposition (September 4, 2008) about an email that he received from Shannon Phillips from the Oklahoma Conservation Commission (labeled as Exhibit 27) which documented:

elevated nutrient concentrations and dramatic increases in periphyton growth

attributed by Ms. Phillips to cattle grazing in Cedar Hollow, a subwatershed of the IRW which was believed to not have received land application of poultry litter.

Dr. Olsen testified in the Preliminary Injunction hearing that he could discriminate among poultry, WWTP, and cattle as sources of constituents in water in the IRW, but he did not articulate a specific criterion (such as his principal component (PC) 1equal to or greater than 1.3 cutoff that he used to determine poultry impact) to assign a water sample to the cattle impact category. Dr. Glenn Johnson (2008, pages 40 to 50) describes in detail how Dr. Olsen's arguments changed from the Preliminary Injunction stage of this case to his September, 2008 deposition. As Dr. Johnson shows, all four of Dr. Olsen's cattle-impacted samples had PC1 greater than 1.3, above his unique poultry waste signature threshold, and Dr. Olsen was unable to obtain separation in his PCA analyses between cattle and poultry impact. When confronted with new evidence regarding PCA results for samples that Dr. Olsen believed to be cattle impacted, his opinion that cattle are not an important source in the IRW never changed, only the line of reasoning that he needed to adopt to reach that conclusion. In the final analysis, it appears that Dr. Olsen believes that cattle cannot be important sources of constituents to stream water because he is unable to see a strong signal in his PCA. As described in Section III.12 and in the expert reports of Dr. Glenn Johnson, Dr. Larson, and Dr. Chadwick, Dr. Olsen's PCA is not a scientifically legitimate tool for excluding cattle, or any other potentially important nonpoint source, as significant in this watershed.

I located 11 bacterial TMDL reports that were completed for the Oklahoma DEQ and that provided an estimate of what constituted the most important source of fecal bacteria to the subject watersheds. The locations of the watersheds for which those TMDL reports have been completed are shown in Figure 6-2. Together, they cover much of the state of Oklahoma, including watersheds to the north and south of the IRW, including areas of intensive poultry farming. Four of the 11 TMDL reports (Boggy Creek, North Canadian River, Lower Red River, and Little River) stated that livestock was estimated to constitute the largest contributor of fecal coliform bacteria loading to land surfaces AND that cattle appeared to be the most likely livestock source of fecal bacteria to streams. All of the remaining 7 TMDL reports stated that cattle appear to represent the most likely or largest source of fecal bacteria. Thus, there are 11 TMDL reports completed for the state of Oklahoma, of which I am aware, that single out one source of fecal bacteria as being most important. **All** of those single out cattle. If cattle represent the major source of fecal indicator bacteria in these watersheds, it is logical to assume that they may also represent an important source of P. It therefore seems curious that Plaintiffs' consultants dismiss the importance of cattle in the IRW based on the weak argument that cattle merely recycle P already present within the watershed (See detailed discussion of this issue in Section III.17 of this report) and Dr. Olsen's inability to find a strong signal for cattle waste in his PCA analysis (See discussion of the numerous problems with Dr. Olsen's PCA in Section III.12). In fact, the density of cattle in the IRW is generally equal to, or greater than, the densities of cattle in these 11 Oklahoma watersheds for which TMDL analyses suggested cattle as being recognized as the most likely source of fecal indicator bacteria (Figure 6-3).

Not only are cattle known to be important sources of NPS pollution to streams, but in addition, reducing the amount of time that cattle spend in streams and riparian zones via installation of off-stream watering sources has been shown to dramatically decrease bank erosion and improve stream water quality in cattle-impacted streams. For example, Sheffield et al. (1997) installed a watering trough and subsequently documented decreased cattle use of the adjacent stream in Virginia. Stream bank erosion was reduced by 77%. Flow-weighed total P concentration in the stream outlet decreased from 0.2 mg/L to 0.07 mg/L, a decrease of 65%. Total suspended solids were reduced by 89%. Fecal coliform bacteria concentration was reduced by 51%. Similarly, in a study of BMP effectiveness on dairy farms in Oregon, Sullivan et al. (2004) demonstrated a reduction by about 74% in FCB concentrations in stream water for a stream that passes through pasture land subsequent to installation of best management practices that included riparian fencing and off-stream watering for cattle. Plaintiffs' consultants contend that cattle are not important contributors of fecal indicator bacteria and other constituents to streams because they merely recycle nutrients that are already present on pasture land. If this was true, it would not be possible to improve water quality conditions via improved cattle management. Improved cattle management, via BMP installations, is a major focus of watershed restoration work nationwide. Federal and state governments and stakeholder groups spend considerable resources on these efforts. The reasons for this are simple: cattle are important contributors of NPS water pollution; improved cattle management contributes to improved water quality. It seems unbelievable to me that Plaintiffs' consultants do not understand this.

<u>Septic Systems</u>

Septic systems are often considered to be one of the most common and significant sources of stream pollution in rural residential areas (Novotny and Olem, 1994, page 483). Stream pollution from septic systems is primarily due to two pathways: 1) subsurface transport of mobile pollutants such as nitrate via shallow discharge of aquifers into the receiving water, mostly during base flow, and 2) movement of septic effluent to the ground surface when the septic system is not functioning properly (Novotny and Olem, 1994, page 483).

My analyses suggest that approximately 76,000 (Table 4-1) people in the IRW live in communities that do not have central waste water treatment facilities. These people can be assumed to have septic systems for disposal of their household waste water. An unknown percentage of these septic systems are not adequate to protect surface water quality.

According to the Illinois River Basin Plan (Haraughty 1999), constructed by the Oklahoma Conservation Commission for the portions of the IRW that lie within Oklahoma, up to 75% of the septic systems in portions of the IRW may be inadequately constructed or situated. In addition, Engineering Services, Inc. (2004) reported results of septic system surveys in Tontitown and Highfill, Arkansas. They found that 43% of surveyed septic systems in Highfill and an unknown percentage in Tontitown had reported failures, including surfacing sewage, sewage backup, and surface discharge of gray water. Less than 30% of the septic systems had valid permits.

Thus, there is reasonable basis for assuming that an appreciable percentage of the septic systems that serve roughly 76,000 inhabitants of the IRW have some problems associated with their operation or location. As a consequence, it is probable that septic systems can contribute substantial amounts of P and fecal indicator bacteria to streams in the watershed. This source of P and fecal indicator bacteria to streams in the IRW was not fully considered by Plaintiffs' consultants in this case. In addition, Plaintiffs' consultants did not collect any samples in the IRW that were intended to shed light on movement of P, fecal indicator bacteria, or other constituents from septic systems into streams within the watershed.

Bacterial TMDL analyses conducted for ODEQ routinely include an assessment of septic system contribution to overall bacterial loads to rivers in Oklahoma that are 303(d) listed for fecal indicator bacteria. These include the following TMDL reports:

- Canadian River (Parsons 2006b, 2008d)
- North Canadian River and Shell Creek (Parsons 2006a)
- Lower Red River (Parsons 2007c)
- Neosho River (Parsons 2008c)
- Washita River (Parsons 2007a)
- Little River (Parsons 2007d)
- Arkansas River Segments and Haikey Creek (Indian Nations Council of Governments 2008)
- Sans Bois Creek (Parsons 2008a)
- Boggy Creek (Parsons 2007b)
- Upper Red River (Parsons 2008b)

Plaintiffs' consultants did not conduct any analyses to determine the potential impacts of septic systems in the IRW. Dr. Fisher acknowledged in his September 4, 2008 deposition (pages 513-514) that such an effort was not part of his analysis in this case.

Given the rather routine inclusion of potential septic system contributions of fecal indicator bacteria to streams as part of the TMDL process conducted for ODEQ in watersheds throughout Oklahoma, an assessment of nonpoint sources within the IRW should include an evaluation of the potential importance of septic systems as sources of NPS pollutants in this watershed. Such an evaluation was not conducted by Plaintiffs' consultants in this case.

Plaintiffs' consultant, Dr. Engel, actually found a significant relationship between the presence of septic systems and stream P concentration in his analyses of a set of comparative subwatersheds. He dismissed, without any reasonable basis, the relevance of this finding as an artifact of the cross-correlation between poultry house density and septic system distribution. In fact, he could have just as easily dismissed the relevance of his correlation between poultry house density and stream P concentration as an artifact of the same cross correlation. See further discussion of this issue in Section III.8 of this report. In Dr. Engel's Appendix G, he presents less than two pages of analysis that provide the foundation for his dismissal of his observed strong correlations between septic system density and stream P concentrations in his high flow basins in the IRW. He states that:

> ***The Oklahoma Department of Environmental Quality (1997) investigation of septic systems in the Illinois River concludes "systems identified in this study were found to pose no apparent threat to the quality of the Illinois River."***

Examination of that ODEQ (1997) report yields a very different picture than was presented by Dr. Engel. First, the ODEQ (1997) report consists of only six pages of text, some site maps, and tables; it includes no in-depth analysis of anything. Second, the study did not investigate residential septic systems (except where multiple residences used the same system); rather, it focused on 59 non-residential septic systems (i.e., schools, stores, taverns, etc), three community waste water treatment plants, and eight pit privies. Data were collected over a two-week period in July 1997 by interviewing system owners/operators. No field data were collected: no water samples, no runoff evaluation, no evaluation of possible system malfunctions, no determination of stream water quality in proximity to the sites included in the study. Not one of the tens of thousands of individual residential septic systems in the IRW was included. Data were collected by interview; such data included the type of system, type of use, number of users, etc. Distances between each of the 59 systems studied and the nearest stream were calculated. ODEQ's estimates of probable flow in these non-residential systems were generally low, and the systems evaluated were mostly located a fair distance from the nearest stream. On this basis, ODEQ (1997) concluded that these investigated systems posed no apparent significant threat. No conclusions were drawn by ODEQ regarding any potential threat from the tens of thousands of individual residential septic systems in the IRW, either individually or collectively. Dr Engel's contention that this study provides adequate basis for his dismissal of the importance of septic systems in the IRW is without merit.

Dr. Engel also attempted (page G-1 of his expert report) to evaluate P load from septic systems in his 14 study subwatersheds, and claimed that his calculations showed that P load in the small study streams exceeded P loads from the residential septic systems in those watersheds. Even if his calculations are correct, this reveals nothing about the importance of septic systems watershed-wide in the IRW. Furthermore, Dr. Engel appears to not understand that the overall load within the watershed does not determine the extent of possible stream contamination; pathways for pollutant transport must also be considered, and were not considered by Dr Engel in his inadequate assessment of the potential for septic systems to contribute pollutants to streams in the IRW. Furthermore, it is not reasonable to assume that there is one primary source of P contribution to streams in this watershed, given the mix of land uses and large numbers of people and animals. Plaintiffs' consultants' apparent search for evidence that might incriminate one source type is not defensible. There are many source types; each is widely distributed; the relative importance of sources in one area is not necessarily the same as the relative importance in other areas. In his Appendix G, Dr. Engels concludes:

> ***Based on this analysis and the Oklahoma Department of Environmental Quality report on septic systems [**discussed above**], the septic systems in the high flow watersheds are not the primary source of P exports in runoff and baseflow.***

Again, Dr. Engel's search for the "primary source of P exports" is conceptually flawed before he begins his analyses.

As detailed above, Dr. Engel provides little information that would actually help in a determination of how important septic systems are to P contributions to streams throughout the watershed. The ODEQ study contributes no useful information for addressing this question. The loads calculations offered by Dr. Engel ignore the importance of transport from source location to stream, the diversity of conditions across the landscape, the large number of septic systems that occur in the IRW, and the overwhelming likelihood that a great many NPS sources (rather than one "primary" source) are involved in contributing P to stream waters in the IRW.

Erosion

It has been well recognized for more than 25 years that erosion is an important source of NPS water pollution. Novotny (1980) stated:

> ***Since a major portion of nonpoint pollution is associated with sediment, understanding the process of erosion and sediment movement and deposition is important.***

Nevertheless, Plaintiffs' consultants did not undertake a study of erosion and erosion sources of P in the IRW. Plaintiffs' consultants' collection and analysis of sediment cores from Lake Tenkiller is insufficient as a basis for quantification of watershed sources of P associated with erosion. This is, in part, because sediment is retained at multiple locations throughout the watershed. The failure of Plaintiffs' consultants to conduct an assessment of erosion and associated P is a substantial oversight, given the extensive amount of construction-related land clearing actions within the watershed in recent years, as well as the extensive network of roads and the access to streams of large numbers of cattle, which trample vegetation and thereby cause erosion from riparian areas. All of these are issues and actions that would be expected to accelerate erosion within the watershed. None of them were adequately addressed by Plaintiffs' consultants in their sampling program or interpretation of data.

Erosion is a common and well known source of P to stream water. Erosion is not specific to urban or to agricultural land, but rather occurs watershed-wide. Nevertheless, there are certain types of land use that tend to promote higher levels of erosion than others. These are the land uses that disturb soils and remove vegetative cover.

Suspended sediment loads of many rivers have increased up to 10-fold as a result of land use changes in the watershed (Novotny 1995, p. 112) . The activities that cause the most disturbance, and therefore the highest amount of erosion, are generally known to include deforestation, construction site erosion, and intensive agriculture (including row crops and high concentrations of livestock in feedlots or on pasture lands) on highly erodible lands (Clark 1985, Novotny 1995,

p. 112). Among the various environmental effects of increased erosion is the fact that sediment carries nutrients, including P, and metals. Large amounts of sediment in stream waters originate from urban areas (Novotny 1995, p. 114). Sediment yields from urban developing areas can be very high, reaching values up to 50,000 tons of sediment per square km per year (Novotny 1980, 1995, page 115).

It has long been recognized that movement of P from the land to stream water is often caused largely by erosion (Smith et al. 2001, Weld et al. 2001). Erosion can be associated with any land disturbing activity within the watershed. All land disturbing activities can therefore result in the addition of sediment to streams. In a study of North Carolina streams, construction activities caused the highest erosion rates (Lenat and Crawford 1994). Erosion is also often strongly associated with the presence of roads, especially dirt roads, and the ditches and culverts that are found along and across roads. Land clearing activities, including logging, road building, and row-crop agriculture, have long been known to be important sources of sediment to streams (cf., Birch et al. 1980). Such erosion-causing activities can result in substantial contributions of P to drainage water (Hobbie and Likens 1973, Birch et al. 1980, Sullivan et al. 1998a, Sullivan et al. 1998b). For example, Hobbie and Likens (1973) found a 12-fold increase in P flux in a deforested watershed compared with its control. Cattle and other livestock that are permitted uncontrolled access to riparian areas cause sloughing of stream bank soils and elimination of stream bank vegetation (Novotny and Olem 1994, page 683). Pastureland becomes a source of NPS pollution when proper erosion control practices are not in place or when livestock are allowed to approach or enter surface waters. Overgrazing and permitting livestock to approach and enter water courses are major polluting activities on pastures and rangelands. Novotny and Olem (1994, page 686) concluded that, if such activities are controlled, pollution from pastures and rangelands may be minimal.

There are 5,169 miles of road in the IRW, 54% in Arkansas and 46% in Oklahoma, based on U.S. Census data for 2000. Of the roads in the IRW within Arkansas, about 52% are paved and the remainder are dirt, gravel, or otherwise unimproved roads (U.S. Dept. Commerce, Census TIGER files for the year 2000). Dirt roads generally contribute more erosion than do paved roads. The unpaved roads, in particular, can be important sources of erosion to streams, and that erosion can carry large quantities of P. In some watersheds, erosion from roads and other disturbances can constitute the dominant source of total P in streams (Sullivan et al. 1998a,b).

Roads in the IRW contribute an unknown amount of sediment-associated P to streams. In addition, because of the impervious nature of road surfaces, they can undoubtedly be effective vehicles of transport to streams for fecal indicator bacteria deposited on the road surface. Plaintiffs' consultants did not assess the importance of roads, or of other important erosion sources, as potential contributors of NPS pollutants to streams in the IRW.

In addition to erosion from construction sites, roads, and associated ditches and culverts, stream bank erosion can be an important source of sediment to streams, along with its accompanying P load. Stream bank erosion is typically dependent on soil characteristics and the extent to which riparian vegetation is disturbed. Trees and some species of shrubs and herbaceous plants tend to have extensive root systems that help maintain the integrity of the stream bank and limit bank erosion. Cattle grazing in the riparian zone, which is prevalent in the IRW, reduces the vegetative cover, thereby increasing the potential for bank erosion to occur. The Oklahoma Conservation Commission's Comprehensive Basin Management Plan for portions of the IRW within

Oklahoma (Haraughty 1999, page xi) recognized the importance of this issue, and concluded that:

> ***Bank erosion along the Illinois River and its tributaries poses a substantial threat to the system. Eroding banks provide sediment, gravel, and nutrients which destroy valuable land, degrade water quality, destroy critical aquatic habitat, and eventually fill in Lake Tenkiller. This bank erosion is often caused by elimination or poor maintenance of the riparian zone, bridge construction, upstream or downstream changes in channel morphology and/or various upstream land use changes. Estimates of the loading from the bank material suggest that eroding banks contribute a significant amount of the total nutrient load in streams…***

This conclusion was based on evaluation of several sources of data on bank erosion in the IRW, including characterization of selected stream bank areas, estimation of long-term erosion from aerial photographs, and results of a short-term bank erosion study. It was estimated that, overall, the Illinois River became an average of 18% wider between 1979 and 1991, as a consequence of bank erosion. Haraughty (1999, page 44) estimated that 3.5 million tons (62 million cubic feet) of material was eroded into the river from the stream bank between 1979 and 1991. The Baron Fork once sustained a canoe float industry, but has become too shallow to canoe as a consequence of erosion (Haraughty 1999, page 101). Given the importance of erosion in the IRW, and the fact that its importance is well-recognized and described in the OCC's Comprehensive Basin Management Plan, it is improper that Plaintiffs' consultants would ignore this issue in formulating their sampling plan and in interpreting NPS issues in this watershed.

Grip (2009) also provided estimates of bank erosion along a 59-mile stretch of the Illinois River from Lake Frances to Lake Tenkiller. Grip (2009) estimated, based on examination of maps and aerial photographs, that over 15 million cubic yards of sediment have been relocated within this section of river since 1972. Grip (2009) stated that he would expect that only a fraction of that eroded sediment has reached Lake Tenkiller. Studies of sedimentation rate in Lake Tenkiller would be expected to only reflect a portion of the erosion contributed to the Illinois River and its tributaries; the balance would remain in the stream channels and various impoundments that exist in the watershed.

Novotny (1995, p. 115) concluded that the most important sources of erosion include land-disturbing agriculture (especially when spring rains fall on frozen soils), urban areas (especially exposed bare soils and street dust), road construction, logging, strip mining, and stream bank erosion (especially associated with loss of riparian vegetative cover). Neither poultry operations nor pasture lands were listed by Novotny (1995) as being among the most important sources of erosion, although livestock access to riparian zones and to stream channels adjacent to pastures can be important.

Erosion tends to transport primarily the fine particle (clay) and organic matter fractions of the soil from land to stream water. These can be relatively rich in P. Therefore, eroded soil is often enriched in P by a ratio of two or more as compared with particles that remain behind in the soil (Brady and Weil 1999, page 547).

Nutrient enrichment of lakes has been shown to result from NPS inputs associated with conversion of land from native cover to agriculture and urban land use (Stoermer et al. 1993, Schelske and Hodell 1995, Reavie and Smol 2001, Jones et al. 2004). Croplands have been shown to be particularly well correlated with nutrient concentrations in streams (Perkins et al.

1998) and reservoirs (Jones et al., 2004) in Missouri. For example, Jones et al. (2004) found that the percent cover of croplands explained 60% to 70% of the variation in the concentrations of total P and total N in Missouri reservoirs.

Novotny and Olem (1994, p. 247) concluded that general land disturbance by agriculture or construction can increase erosion by two or more orders of magnitude (factor of 100 or more). They further concluded that the highest rates of erosion typically result from deforestation, construction site erosion, and intensive agriculture on highly erodible lands (Novotny and Olem 1994, page 248).

The potential for soil erosion and associated nutrient export increases with soil disturbance (Pitois et al. 2001). Disturbed soils are more exposed to the weather and therefore prone to erosion. Erosion generally controls the movement of particulate P in landscapes (Sharpley et al. 1993). The particulate P movement on agricultural land is a complex function of rainfall, irrigation, runoff, and soil management factors that affect erosion.

Erosion associated with roads has been studied in Arkansas. For example, the Watershed Conservation Resource Center (2005) assessed the contribution of sediment from unpaved roads in three subwatersheds of the Strawberry River watershed in Arkansas, using the U.S. Forest Service Water Erosion Prediction Project modeling module. The study watersheds have a total area of 92 square miles. A survey was conducted of 10% of the publicly owned unpaved roads to determine slope, distance between water diversions, width, road characteristics, presence of ruts, presence of ditch vegetation, fill width, and fill grade. These variables provided inputs to the modeling effort, along with soil texture and rock content, climatic data, and traffic levels. The sediment loads from publicly and privately owned unpaved roads were estimated to be 1,500 tons and 1,412 tons (+/- 50%), for a total of 2,912 tons/yr. Averaged across all unpaved roads in the study area, the estimated sediment entering a stream was 18.8 tons per mile per year.

There are 80 miles of publicly owned and 64 miles of privately owned unpaved roads in the study area considered by the Watershed Conservation Resource Center (2005). The total unpaved road density is 1.6 miles of road per square mile. This compares with more than 1,300 miles of unpaved road in the Arkansas portion of the IRW, yielding an unpaved road density of 1.8 miles of unpaved road per square mile of watershed in the Arkansas portion of the IRW. Thus, the density of unpaved roads in the Arkansas portion of the IRW is slightly higher than is the density of unpaved roads in the portions of the Strawberry River watershed in Arkansas, for which it was estimated that nearly 19 tons of sediment enter the stream system through erosion each year for each mile of unpaved road.

Harmel et al. (1999) also recognized that bank erosion has introduced concern about resource conditions of the Illinois River. They conducted a study of a 101 km stretch of the river from Lake Frances to Lake Tenkiller to quantify erosion rates. Short-term erosion was measured with bank pins and cross-section surveys after four 2- to 2.5-year return period flow events between September 1996 and July 1997. The cumulative erosion from these four rain events averaged 1.4 meters. Long-term erosion was evaluated from aerial photographs taken in 1979 and 1991. Lateral erosion during that 12 year period averaged 16 m, or 1.4 m/yr on 132 eroding stream banks.

Other Potentially Important Sources

There are likely more than 200,000 large mammals (livestock and wild deer; Clay 2008) in the IRW, in addition to the approximately 200,000 cattle discussed above. These other livestock include, in particular, swine, horses, and sheep (Clay 2008). In some instances, these livestock have direct access to streams and riparian zones. In other instances, livestock manure is land applied (Clay 2008). The potential for these animals to contribute P and fecal indicator bacteria to streams in the IRW was not fully addressed by Plaintiffs' consultants.

Wildlife is a well-known contributor of NPS pollutants, especially fecal indicator bacteria, to streams. Myoda (2008) discusses the importance of wildlife as a bacterial source in the IRW.

Many species of wildlife preferentially utilize riparian or stream habitat, thereby increasing the likelihood that fecal material will be deposited in, or immediately adjacent to, streams. Plaintiffs' consultants did not fully consider the importance of wildlife as potential causes of fecal indicator bacteria above water quality standards in streams of the IRW.

Based on the affidavit and materials provided during the Preliminary Injunction hearing by Plaintiffs' consultant, Dr. Lowell Caneday (2008), there are approximately 155,500 recreationists per year on the Illinois River in Oklahoma. Although I make no attempt to verify or substantiate Dr. Caneday's estimate, there clearly are many recreationists using this river, especially during the summer recreation period, May through September. Toilet facilities have not been adequate to support such river use (Haraughty 1999), especially given the high estimate of the numbers of people who float the river (76% of total users) and are therefore away from developed facilities. The volume of human waste deposited along the river and the shores of Lake Tenkiller by these users, and the potential for such waste to contribute P and fecal indicator bacteria to the stream system was not evaluated by Plaintiffs' consultants for this case. Analyses reported by Defendants' expert, Dr. Jarman (2008) include findings of substantial recreational use within the watershed over a period of 40 years and resulting contribution of P and fecal bacteria.

Plaintiffs' consultants focused their attention on land application of poultry litter in the IRW, but largely ignored land application of swine manure, commercial fertilizer, and biosolids as potential sources of P and/or fecal indicator bacteria. There are about 166,000 swine in the watershed. This population represents a large quantity of fecal material which is probably land applied (Clay 2008), presumably partly in the watershed. Plaintiffs' consultants did not collect any samples or conduct any analyses in an attempt to determine the importance of any of these potential sources of land applied fecal materials and chemical fertilizers as contributors to stream water quality. I do not have information on the locations of land applied swine manure or commercial fertilizer in the IRW. Dr. Jarman determined the general locations of biosolids applications. Application areas generally correspond with locations of waste water treatment plants.

Lake Frances

Lake Frances is a man-made impoundment located on the main stem Illinois River in Oklahoma, along the Arkansas state line. The dam that forms Lake Frances was breached in about 1990. As a consequence, soft sediment that had been deposited in the former lake bed during the years of reservoir impoundment are now part of the flood plain and are more available for erosional processes to contribute some of this sediment (along with its P load) to the river. This would be expected to occur primarily during high flow conditions. Thus, the old Lake Frances lake bed is now a potential source of sediment, P, and other constituents to the Illinois River as it crosses the state line from Arkansas into Oklahoma (Haggard and Soerens 2006).

It is likely that the Lake Frances lakebed stored P in its sediments, especially during the years when P concentrations in the river were high (Haggard and Soerens 2006). This stored P can now be released back into the river when dissolved P in the water is less than equilibrium P concentrations with the sediment. In addition, resuspension of P-enriched sediment, due to wind (Søndergaard et al. 1992) or high stream flow can increase the concentration of P in stream or lake water.

Based on experiments using lake sediment cores from Lake Frances, Haggard and Soerens (2006) found that bottom sediments in Lake Frances have the ability to release phosphate into the river water. They measured sediment P fluxes under aerobic conditions that rivaled those measured under anaerobic conditions in many eutrophic reservoirs. They concluded:

> ***Thus, bottom sediments in Lake Frances have the potential to release high amounts of P and also to maintain P concentrations downstream at the Illinois River elevated above Oklahoma's Scenic River TP criterion (0.037 mg/L)…It is possible that remediation strategies should be considered for Lake Frances and the P- rich sediments stored within the former impoundment, if Oklahoma's Scenic River TP criterion will be achieved.***

To the best of my knowledge, Plaintiffs' consultants have not considered the influence of Lake Frances on TP concentrations in the Illinois River in any of their analyses.

Nevertheless, the potential importance of Lake Frances as a source of P to the Illinois River has been recognized for some time. The Comprehensive Basin Management Plan, prepared by the Oklahoma Conservation Commission (Haraughty 1999) stated:

> ***The collapse of the Lake Frances Dam in 1991 resulted in an additional source of nonpoint source pollution to the Illinois River basin in Oklahoma. The collapse exposed several hundred thousand cubic meters of nutrient-enriched lake bed to potential erosion.***

Haraughty (1999, page 53) went on to state, in discussing Lake Frances:

> ***It is difficult to imagine that water quality in the river can be much improved until this situation is addressed as a high potential exists for release of sediment to the river.***

The extent to which P is contributed to the Illinois River by Lake Frances was examined in a study by Parker et al. (1996). Samples of river water were collected at the Highway 59 bridge crossings above (n=130) and below (n=94; near Watts) the state line over a one year period in 1995 and 1996. Weekly samples were collected and augmented with additional storm samples. The average total P above the lake was 0.28 mg/L and below the lake it was 0.33 mg/L. Parker et al. (1996) reported that:

> ***The percent difference of 16.4% and t-test results of 0.059 for TP give borderline results as to whether a difference exists in the upstream and downstream TP concentrations.***

Thus, results of the statistical comparison were inconclusive. It is noteworthy, however, that the difference in the average results between the two stations was actually larger than the 0.037

mg/L water quality standard for TP. This suggests that if there were no sources of TP in Arkansas at all, the concentration of TP in the Illinois River in Oklahoma, just downstream from the Arkansas state line, might exceed the water quality standard solely on the basis of P contributed at the Lake Frances location, and the adjacent contributing area, between the two Highway 59 bridge crossings. Parker et al. did find a statistically significant increase (by 42%) in the concentration of total suspended solids (TSS) from the upstream to the downstream sampling location, supporting the hypothesis that the former Lake Frances lake sediment may be eroding and contributing sediments to the Illinois River.

Haggard and Soerens (2006) evaluated P release from sediments that had previously accumulated in Lake Frances. Haggard and Soerens (2006) stated:

> ***State agencies at the Arkansas-Oklahoma River Compact Commission reported conflicting trends in P concentrations and loads at the Illinois River during 2002, where P was decreasing in Arkansas and increasing in Oklahoma. One potential confounding factor in the water-quality monitoring programs between states may be that Arkansas monitors the Illinois River upstream of a small impoundment*** *(Lake Frances)* ***and Oklahoma monitors downstream from the spillway.***

Sediment equilibrium P concentrations in laboratory studies were found to range from 0.05 to 0.20 mg/L, which is greater than the total P standard applicable to this river from the Lake Frances outlet downstream through Oklahoma. Haggard and Soerens (2006) speculated that P that had been previously stored in the Lake Frances sediments during the years when P concentrations in river water were especially high, are now being released from sediment into the river water column. This would be expected to occur, in particular, when dissolved P in the river is less than sediment equilibrium concentrations, and when oxygen is depleted at the sediment/water interface or sedimentary P is introduced back into the water column by wind resuspension of bottom sediments. The latter process is known to occur in shallow, nutrient-rich lakes (Søndergaard, 1992). In discussing their findings, Haggard and Soerens (2006) concluded:

> ***This study showed the potential for bottom sediments in Lake Frances to increase P transport at the Illinois River, especially if water column dissolved P concentrations upstream from Lake Frances decrease…***

Summary

It is clear that there are a multitude of point and nonpoint sources of P and fecal indicator bacteria to the IRW. The Oklahoma Conservation Commission's Comprehensive Basin Management Plan for portions of the IRW that occur within Oklahoma (Haraughty, 1999) stated:

> ***However, agriculture cannot be cited as the sole source of water quality problems in the watershed... Additional nonpoint sources include recreation, the remains of Lake Frances, urban runoff, gravel mining, and streambank erosion. Combined sources*** *(sources with essentially both point and nonpoint source pollution)* ***include nurseries and urban runoff.***

The importance of these, and other (i.e., pets, row crops, hobby animal husbandry), widely distributed sources is cumulative. Some may also be important individually. For example, Haraughty (1999, page xiii) concluded that a single nursery on the shores of Lake Tenkiller contributed more than 1% of the total P load to the lake in irrigation return flows alone (irrespective of storm contributions), although controls have more recently been placed on the irrigation water at this site.

The Illinois River Management Plan (OSRC, OSU, and NPS 1999) recognized the importance of these multiple sources of NPS water pollution in the IRW. They identified a series of management goals aimed at corridor values, recreational resources, and water quality. The listed water quality management goals included:

- Minimizing alteration of stream habitat and sedimentation due to destabilization of stream banks,
- Reducing the loading of nutrients and chemicals from commercial nursery tailwater and pollutant loading into the river from urban runoff,
- Reducing nutrient inputs due to animal waste by requiring producers to complete and implement approved conservation plans,
- Protecting riparian areas from the impacts of livestock,
- Assisting in the collection of water quality data and public education.

Since the management plan was written in 1999, positive steps have been taken to address many of these goals. But it is important to note that the focus outlined for these management goals recognized that there are many contributors to NPS water pollution in the IRW, not one. Plaintiffs' consultants' claims that land application of poultry litter constitutes "the primary source" do not agree with results of previous assessments.

The importance of these various sources of constituents to streams in the IRW was almost completely overlooked by Plaintiffs' consultants. For example, Dr. Glenn Johnson (2008, page 71) reported the results of his evaluation of Dr. Olsen's PCA analyses. He stated that Dr. Olsen's SW3 and SW22 PCA runs included only 15 samples presumed or collected with the intent of characterizing sources other than poultry (2 cattle edge-of-field, 3 cattle impacted springs, 4 WWTPs, and 6 Tahlequah urban stream samples). Every one of those samples exhibited PC scores that fit Dr. Olsen's criterion for indicating what he characterizes as his unique poultry waste signature. Even if Dr. Olsen's signature does provide some interpretable information regarding contributions of various constituents to water in the IRW, it does not indicate what the source or sources of those constituents might be. Dr. Olsen largely ignored or seriously under-represented in his analyses most of the sources expected to be significant contributors in this watershed.

7. The Plaintiffs' consultants contend that P, fecal indicator bacteria, and other constituents move directly from pasture to stream, but they do not demonstrate such movement. They incorrectly claim that their edge-of-field samples demonstrate such movement.

<u>Plaintiffs' Consultants Did Not Exhibit a Clear Understanding of What Their Edge-of-Field Samples Were Intended to Represent, and Did Not Exhibit an Understanding of How to Interpret Their Edge-of-Field Data.</u>

Plaintiffs' edge-of-field sampling effort was ill-conceived, poorly defined, and did not produce data that could be useful in evaluating the extent to which land application of poultry litter, or any other potential source of P or fecal indicator bacteria, actually contribute to stream water quality in the IRW. Plaintiffs' consultants were confused about how these samples were intended to be collected. The standard operating procedures (SOP) for edge-of-field sampling, prepared by Dr. Fisher and Mr. Brown (SOP 10-01, Last revised 02/05/2007) stated that these samples would include:

> ***Samples collected directly from naturally ponded or flowing water and from passive samplers installed to collect water running off fields.***

The SOP further stated that:

> ***In order to collect a representative sample, the sampler should, from a consideration of local topography or direct observation of water flow, determine that the water to be collected is field runoff.***

The SOP failed to mention, perhaps because Plaintiffs' consultants did not recognize, that at most locations on relatively flat pasture and mixed land-use lands, it is in fact not possible to consider topography and determine whether or not water that is observed in a ditch or on the surface of the land actually came off a nearby field, or came from some other location. This is especially problematic when the sample itself is collected from a roadside ditch (which, based on review of photographs of edge-of-field sites, appears to have often been the case). In short, the SOP described a sampling objective that could not possibly have been satisfied at most sampling locations.

The SOP did not specify where edge-of-field samples would be collected; rather it indicated that:

> ***Personnel from Lithochimeia or CDM will conduct the EOF sampling at each opportunistic location.***

It was not defined what would or would not constitute an appropriate "opportunistic location". Thus, field personnel were free to search the landscape where they thought or knew that poultry litter had been land applied, and then attempt to sample any water available. As is evident from the field photographs, many of the selected sampling locations contained roadside ditches from which water could readily be collected. Field personnel were not instructed in the SOP, nor apparently did they elect on their own, to document exactly how and where each edge-of-field sample was collected. There does not seem to be any documentation of which edge-of-field samples were collected using a passive sampler, which were collected by dip sampling, which were collected from a roadside ditch, which were collected from ponded water (and of those which may have been roadside ponds, in-pasture ponds, etc.). There was no documentation that permission was granted to the field personnel to sample on private property, and Dr. Fisher acknowledged in his September 4, 2008 deposition (page 538) that they did not have access to the private property for edge-of-field sampling. Therefore, it is reasonable to assume that many samples were collected from roadside locations. They did not have access to collect them elsewhere in most cases. There was apparently no documentation regarding how many of the samples were collected from flowing water. Mr. Brown was asked about this in his August 26, 2008 Deposition (transcript, page 174). In referring to recording important information on the actual locations and field conditions associated with edge-of-field samples, Mr. Brown responded as follows:

> Q. ***Was it recorded when the sample was taken what the status of the water was, and what I mean by that was whether it was taken from a puddle, pool, ditch, whether it was standing, flowing?***
>
> ***A. That record did not seem to be consistently recorded in the field books.***
>
> ***Q. Was it required of the field teams?***
>
> ***A. It was requested. I don't know that it was required.***

The SOP specified that:

> ***Sample locations will be selected at public right-of-way locations adjacent to contract growers' farms or company-owned facilities where aqueous runoff from the facilities is occurring during or immediately after precipitation events.***

No information was provided in the SOP to define what would constitute "aqueous runoff" or how field personnel should determine how the water in a puddle or ditch got there. The phrase "where aqueous runoff from the facilities is occurring during or immediately after precipitation events" implies that the SOP required collection of water that was in the process of moving across the landscape from a field to a stream. I don't understand how Dr. Fisher and Dr. Olsen could possibly have expected that their field personnel could have implemented such a sampling program. No information was provided to instruct field personnel how they should determine the origin of said aqueous runoff. No information was provided to instruct field staff regarding how to determine if aqueous runoff was actually occurring. I have conducted field research in which I collected during rainstorms edge-of-field runoff from pasture land, subsequent to application of dairy cow manure to the pasture. These samples are very difficult to collect. It is my judgment based on my experience that it would have been impossible for Plaintiffs' field personnel to successfully carry out this ill-defined and poorly-conceptualized SOP for edge-of-field sampling.

Plaintiffs' consultant Berton Fisher was asked in his September 4, 2008 deposition, how many edge-of-field samples were collected where the runoff was moving across the land in a sheet at the point it was sampled. He responded:

> ***Not too many, two or three, and in the protocol for collecting the samples, the sample could be collected if the flow could be determined by one of two methods. Either by directly observing flow or by noting the local slope and topography and determining that flow could have come from the field at issue.***

When asked about her understanding of how and where edge-of-field samples were collected for this case, Dr. Harwood responded (Preliminary Injunction hearing transcript, Volume III, February 21, 2008, page 778):

> ***From what I've been informed, it's usually a ditch.***

Thus, the intention of the Plaintiffs' consultants was to sample water flowing off of fields that had been amended with poultry litter, or to collect runoff from buried passive samplers. But this is not what they did. Only "two or three" edge-of-field samples were collected from water moving across the surface of the field. Plaintiffs' sampling personnel instead collected water if they judged that "flow could have come from the field at issue". That may be good enough for Plaintiffs' consultants, but I see no reason to accept Plaintiffs' consultants' allegations that the water that they collected at their edge-of-field sampling locations that "could have come from the field at issue" was influenced only, mainly, or even slightly by poultry litter that may have been applied to that adjacent field. They simply don't know where that water came from, or what may have influenced its quality.

Dr. Fisher acknowledged in his deposition (page 539) that:

> ***The passive collectors were inadequate at capturing runoff.***

In response, Plaintiffs' consultants modified the procedures for edge-of-field sample collection:

> ***To collect from the ponded water itself or moving water itself***

In fact, as they should have known in advance, neither of these approaches was successful in collecting water in the vast majority of cases. In the end, it appears that they simply collected water from the roadside ditch at many locations. Given this confusion about what was supposed to be collected and in what way, it is especially troubling to me that the field personnel did not provide consistent documentation, in each sampling situation, of what they were collecting and where and how they were collecting it. It is even more troubling that no oversight was provided to guide the field crew in this effort. What is clear is that Plaintiffs' consultants had no idea how to design or implement a proper edge-of-field sampling program.

Dr. Fisher also acknowledged in deposition (page 540-543) that Plaintiffs' consultants did not document what had been applied to the fields that were adjacent to the edge-of-field sampling locations, whether chemical fertilizers were applied, whether liquid dairy or swine wastes had been applied, or which fields had been grazed by cattle. In short, Plaintiffs' consultants do not know what the sources might have been of any P or fecal indicator bacteria found to occur in their edge-of-field samples. These edge-of-field samples therefore have no value in the context of evaluating sources of the constituents of concern to streams in the IRW.

<u>Plaintiffs' Consultants Assumed that P Found in Water in Non-urban Settings in the IRW was Derived from Poultry Litter Spreading, without Investigating the Importance of Other Sources.</u>

Not surprisingly, and as discussed above, the most important sources of P to stream waters in the IRW appear to originate in the urban areas. Obviously, the contribution of such sources would generally not be reflected in Plaintiffs' edge-of-field samples. As described more fully in Section III.6, there are also additional sources of P and fecal indicator bacteria in the agricultural and other non-urban portions of the watershed that potentially could contribute these constituents to puddle or ditch water. These potentially include sources associated with livestock (especially cattle, but also horses and other livestock), land application of animal manures (including poultry, swine, and dairy cattle), septic systems, wildlife, and fertilizer application. Erosion is also a source of P and is common along roads and roadside ditches.

Plaintiffs' consultants incorrectly **assumed** that all P and fecal indicator bacteria contributed to edge-of-field water or to stream water from any source other than waste water treatment plant effluent must have originated from land application of poultry litter. No scientifically defensible evidence was presented to support this claim.

Plaintiffs' consultants collected what they termed "edge-of-field" samples, in an effort to try to establish a connection between streams and fields to which they believed poultry litter had been land applied. However, data derived from these samples failed to demonstrate that P, or any other constituent in those samples, actually was derived from poultry litter, or that any of this "edge-of-field" water actually flowed into any stream. As described below, there were multiple potential and likely sources of water constituents in the immediate vicinity of those edge-of-field sampling locations. Furthermore, because Plaintiffs' consultants did not trace the movement of water from the edge-of-field sample sites to locations down-gradient from those sites, it is not known to what extent the sampled water may have subsequently infiltrated into soil or evapotranspired, as opposed to actually flowed into a stream. If that water subsequently infiltrated into the soil, a substantial component of the P and fecal indicator bacteria concentrations in the edge-of-field water would likely have become adsorbed to the soil. Even if some of the sampled "edge-of-field" water did subsequently flow into a stream, it is not known if that flow was in sufficient quantity, and with sufficient concentration of P or any other parameter, so as to have an appreciable effect on the chemistry or biology of the stream water. This was because Plaintiffs' consultants did not determine the water flow rate at the location of edge-of-field sampling; in fact, they did not consistently determine whether or not the water was flowing, and were uncertain as to whether or not their protocols actually required that the sample be flowing in order for it to be an acceptable sample.

There was a fair amount of confusion among Plaintiffs' consultants regarding what constituted an edge-of-field sample. In his report describing the Plaintiffs' field sampling program, Darren Brown (2008, p. 1-21) stated that these samples were:

> ***representative aqueous samples of runoff from fields…and includes samples collected directly from naturally ponded or flowing water and from passive samplers installed to collect water runoff from fields. Passive samplers were sample collection containers placed in areas where runoff from applied fields was likely to flow during rainfall events. After the rainfall event, the sampler was removed and the collected water transferred to an appropriate container for sample shipment.***

No mention was made by Mr. Brown in his 2008 report of collecting edge-of-field samples from roadside ditches.

Thus, Plaintiffs' consultants made no determination of where the edge-of-field water that they collected came from, what sources may or may not have contributed P or fecal indicator bacteria to that water (or in what quantities), whether or not it was flowing and if so in what volume and flow rate, where the sampled edge-of-field water went down-gradient from where it was sampled, and whether in fact it ever entered a stream. In addition, Plaintiffs' consultant Dr. Berton Fisher (September 4, 2008a deposition, page 459) could offer no opinions regarding what level of P would designate an edge-of-field sample as polluted or contaminated with P. There are no existing water quality standards of which I am aware or which Dr. Fisher could identify in his deposition for P or fecal indicator bacteria in edge-of-field water or roadside ditch water.

<u>Importance of Water Flow Path as a Vehicle for Transport from Field to Stream</u>

In order to understand the issues associated with Plaintiffs' consultants' "edge-of-field" samples, it is helpful to describe how rain water moves off a field during a rainstorm. Rainfall on the surface of a pasture must first wet the surface and eventually fill the surface depressions, creating small puddles and ponded areas. From these, water infiltrates into the soil. Only when the rate of rainfall exceeds the rate of infiltration and when all surface storage is exhausted will surface runoff occur (Novotny 1995, p. 75). Infiltration is largely a function of permeability of soils, pre-storm soil moisture content, and vegetation cover.

Direct runoff can have several components that vary in the extent to which runoff water interacts with soil. This interaction is critical because soils tend to adsorb P and fecal indicator bacteria; water flow across the soil surface (overland flow) has less opportunity than does water flow through the soil for such interaction with soil particles. See further discussion of water flow paths in Section III.11.

Much of the surface runoff, and also much of its P load, is derived from only a small percentage of the watershed (Pionke et al. 1997, Heathwaite et al. 2000). Thus, most of the pasture area does not contribute much overland flow, and therefore does not contribute much P, to the stream. Plaintiffs' consultants did not attempt to identify these hydrologically active areas that contribute disproportionately to surface runoff or to quantify the extent to which they contribute P or any other constituent to stream water. See additional discussion of this issue in Section III.11. Furthermore, Plaintiffs' consultants did not evaluate the extent to which existing guidelines and litter application regulations in Oklahoma and Arkansas effectively reduce or eliminate poultry litter spreading in such areas.

<u>Governmental Recommendations and Regulations Regarding Land Application of Poultry Litter Consider the Importance of Transport Mechanisms</u>

It is because of the processes described above and further in Section III.11 that certain regulations and recommendations have been adopted throughout the United States and in Oklahoma and Arkansas regarding the land application of poultry litter. As described more fully in Section III.19, current regulations discourage or do not permit litter application in close proximity to a stream, on lands that routinely flood, or on frozen soils. The reason that such locations and conditions are specified as inappropriate for litter application is precisely because in such areas and under such conditions, an appreciable amount of runoff can be generated as overland flow, which is much more likely to carry P and/or fecal indicator bacteria to surface waters than are other flow paths. Most pasture areas with loamy soils (such as predominate in the IRW) contribute little Hortonian overland flow (overland flow caused by rainfall intensity exceeding soil infiltration capacity); in contrast, unvegetated soils, such as in row crop agriculture or where livestock have overgrazed and/or trampled the vegetation, generate more Hortonian overland flow. Regulations and recommendations by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), U.S. EPA, and the states of Arkansas and Oklahoma are based on an understanding of these water flow paths and transport processes. Of particular relevance is the guideline that specifies that poultry litter should not be applied within 100 feet of a stream (somewhat closer if a riparian buffer strip is installed). For example, Gburek et al. (2000a) concluded that:

> ***Field studies show that surface runoff is generated primarily from near-stream areas, typically on the order of 30 m or less from the channel for most storms. Hydrograph analysis and soil phosphorus distribution within a small intensively monitored and sampled watershed imply that surface runoff and phosphorus loss occur mainly from an area extending not much more than 60m from the channel. Also, concentrations of DP*** *[dissolved phosphorus]* ***decreased downstream and were more closely related to near-stream soil phosphorus than to the whole- watershed distribution of high phosphorus soils. In the most***

> ***simple sense, the intersections of surface runoff source areas within a watershed with areas of high soil phosphorus are what create the CSAs*** *[critical source areas]* ***controlling phosphorus export. Thus,, phosphorus export may be most efficiently managed by focusing on control of soil phosphorus levels and fertilizer and manure applications in the hydrologically active zones most likely to produce surface runoff.***

Plaintiffs' consultants ignore the existence of these recent recommendations and regulations and their intended effects on the potential movement of P and fecal indicator bacteria off pasture lands and into streams in the IRW.

<u>What do Plaintiffs' Edge-of-field Samples Represent?</u>

A collection of photographs, provided by Plaintiffs' consultants, of edge-of-field sampling is given in Figure 7.1. It appears that the majority of Plaintiffs' edge-of-field samples were collected as standing water found adjacent to pasture land or in a roadside ditch during or subsequent to a rainstorm. In many cases, Plaintiffs' consultants appear to have collected water from a ditch along a road. In other cases, it is not clear from Plaintiffs' consultants' database where and how the edge-of-field samples were collected. Such samples could have represented ditch water of unknown origin, depression storage, or ponding. Plaintiffs' consultants did not consistently record the type of sample collected, the manner in which it was collected, or the potential sources that might have contributed constituents to that water. No effort was made to map the origin, path, or fate of roadside ditches from which many of the edge-of-field samples were apparently collected. Without knowing the origin of the water comprising the edge-of-field samples it is inappropriate to characterize those samples as showing effects of poultry litter application. There are no State water quality standards of which I am aware for water in a roadside ditch or water collected from a puddle on an agricultural field. The presence of high concentrations of P, or any other constituent, in such ditch or puddle water is not directly relevant to protection of stream water quality and reveals nothing regarding the extent to which that P or other constituent may have been derived from poultry litter, cow manure, septic systems, lawn fertilizer, or any other local potential source. Furthermore, Plaintiffs' consultants have presented no data to indicate why the concentrations of P and fecal indicator bacteria in these edge-of-field samples should be considered unusual or of any environmental significance or concern.

Such water might eventually flow into a stream, or conversely it might eventually be lost to evaporation or transpiration by vegetation, or infiltrate into soil. In the case of Plaintiffs' edge-of-field samples, it is completely unknown whether or not that water could potentially influence the quality of stream water, particularly with respect to parameters that tend to adsorb to soils. Heathwaite et al. (2000) described the various hydrological pathways by which P can be transported from agricultural fields to streams. They discussed partial source areas (PSAs), such as channeling of flow along roads, and concluded the following (Page 118):

> ***however, hydrological connectivity with the stream must exist for them to be significant factors in phosphorus transport to receiving waters… Furthermore, the incidence of PSAs is of a low frequency (although the phosphorus loss may be high), thus, their impact remains under-researched.***

Plaintiffs' consultants did not collect data to document the fate of the water that they sampled as edge-of-field. There is no reason to assume that such water would eventually flow into a stream, or if it did flow into a stream that it would do so in sufficient quantity that it could appreciably increase the concentration of P or fecal indicator bacteria in that stream. As far as I am aware, Plaintiffs' consultants did not conduct analyses to determine whether or not standing water or ditch water sampled in their edge-of-field effort actually flowed to any stream. Furthermore, Plaintiffs' consultants did not make a consistent effort to determine whether or not their sampled edge-of-field water was flowing at the time of sampling and did not make any effort to quantify the flow rate of water collected in their edge-of-field sampling program. This is important because both the concentration of a contaminant in the water and the volume of water contributed to a stream are critical items that together determine whether or not that contribution will appreciably affect the quality of that stream. A very small volume of water that contains P concentration that is dramatically higher than the 0.037 mg/L stream water standard cannot be assumed to have a measurable effect on the concentration of P in that stream. To affect the chemistry of the stream, both the concentration of P in the water and the volume of water must be sufficiently high. It is not sufficient, as Plaintiffs' consultants have done, to only collect information on the concentration, to the exclusion of flow. Plaintiffs' consultants also apparently did not make any effort to determine the proximity of their edge-of-field sampling locations to streams. Thus, there is no linkage provided by Plaintiffs' consultants between edge-of-field locations and streams in the IRW. We don't know, nor do Plaintiffs' consultants, where the edge-of-field water came from before it was sampled, what potential sources of water contamination may have impacted it, or where it went down-gradient from the point of sample collection, including whether or not it flowed into a stream. Plaintiffs' consultants merely illustrated that water that they were able to collect near some litter-amended pasture lands, which may have represented roadside ditch water, puddle water, or some other unknown and undocumented classification of surface water that may or may not have been flowing at a rate that was not investigated, often contained relatively high concentrations of certain constituents that may have been derived from cattle, poultry litter, other livestock, pets, septic systems, erosion, and/or road runoff. This type of data cannot be used to interpret the relative importance of any individual NPS source category in the IRW. Furthermore, Plaintiffs' consultants did not sample and appropriately analyze and report streams immediately above and below **any** of the locations from which they contend that edge-of-field water was affected by runoff from poultry litter amended pasture area. Thus, there is no basis for their allegation that the stream water was affected in any measurable way by the quality of the water represented by edge-of-field samples.

Defendants' expert, Dr. Jarman, coordinated a survey of most (n=60) of Plaintiffs' edge-of-field sample site locations during the summer of 2008. His staff photographed each of the sites that they visited, located using GPS coordinates provided by Plaintiffs' consultants. Some example photographs taken by Dr. Jarman's staff are shown in Figure 7-2**.** Based on those photographs, and field notes and recollections of the field staff that visited those edge-of-field collection sites, a table was constructed to indicate potential sources of P and fecal indicator bacteria that were visible from the sample site locations. That table is provided here as Table 7-1. The sampling sites were selected by Plaintiffs' consultants to be adjacent to fields to which they believed that poultry litter had been land applied. Thus, it is not surprising that pasture/hay land was visible at all except one (98%) of the sites. Nevertheless, a roadside ditch was visible at 92% of the sites; Dr. Jarman's staff judged that this was a likely source for collecting the sample in most (88%) cases. In addition, there were roads at all (100%) sampling locations, the majority of which were dirt/gravel roads, which are generally more prone to erosion than paved roads. Although poultry houses could be seen from half of the sites, signs of cattle or horses were visible at nearly as many (45%), as were barns other than poultry (42%). Housing (with probable septic systems, pets, and/or other livestock) were visible from more than three-fourths (78%) of the sites. Thus, there are many potential sources of P and fecal indicator bacteria to the sites sampled by Plaintiffs' consultants in their edge-of-field sampling effort. Plaintiffs' consultants have no idea where the water originated that was the subject of their samples, or what pathways it followed to reach the sampling location. The widespread occurrence of multiple potential sources of NPS pollution in the vicinity of the sampling sites prevents Plaintiffs, or anyone else, from making any informed judgment regarding the source(s) of those constituents to the edge-of-field water. The failure of Plaintiffs' consultants to investigate or document connectivity of edge-of-field sites to streams or to quantify any effects that might occur on receiving waters, makes it impossible to determine whether any of that edge-of-field water could have influenced the quality of stream water in the IRW.

Plaintiffs' consultants **assume** that the P and fecal indicator bacteria that they measured in water samples must have originated from land application of poultry litter. They offer in defense of this assertion Dr. Olsen's Principal Components Analysis (PCA). As discussed at length in the Defendants' expert reports of Drs. Glenn Johnson and Charles Cowan, Dr. Olsen's PCA cannot be used to discriminate among the various potential sources of these constituents in streams within the IRW. There are many problems with the PCA interpretation, as described in detail in these other expert reports. See further discussion of these issues in Section III.12 of this report.

8. *Plaintiffs' correlations between poultry house density and stream P concentration do not demonstrate that poultry house density is the cause of P in stream water. Plaintiffs' poultry house density variable is a surrogate for a number of human activities that are well known to contribute NPS pollution to streams.*

Dr. Engel presented data, including data given in Appendix C of his report, prepared for this case for 14 small subwatersheds in the IRW that were sampled in 2005 and 2006. The analyses reported in that Appendix represented a collaborative effort among Dr. Engel, Dr. Olsen, and Dr. Cox. Some, but not all, of their analyses showed statistically significant correlations between poultry house density (calculated from assumed poultry house locations identified by Plaintiffs' consultants from air photos and ground reconnaissance) within each study subwatershed and total P concentration (and related variables) in stream water. Surprisingly, based on these empirical regression analyses, Dr. Engel (May, 2008, page 42) concluded that the observed correlation between P concentration in stream water and poultry house density showed:

> ***… a cause and effect relationship between poultry operations and phosphorus concentrations in IRW waters. From these analyses, it is evident that poultry waste is a substantial contributor to P in stream runoff and in the baseflow within streams of the Illinois River Watershed.***

Such a statement is well outside the bounds of reasonable science. Every credible scientist knows that correlation does not demonstrate causality. If, in fact, poultry house density is correlated with P concentration in stream water, that correlation does not demonstrate that poultry operations were the cause of P in streams.

Dr. Engel was not the only one among the Plaintiffs' consultants to assert that the observed correlation between poultry house density and stream P concentration can be taken as documentation that the former causes the latter. Similar statements, albeit with softer language, were made by Dr. Stevenson (2008, page 16):

> ***If poultry house density in the watershed is related to nutrients, algal biomass, and DO or pH, then it is highly likely that poultry operations caused these alterations of IRW streams***

As explained more fully below, such statements have no place in a credible scientific assessment.

Many things can be correlated for many reasons and be completely independent of each other. For example, Dr. Fisher presented in his considered materials for the Preliminary Injunction a graph that showed an increase in the number of poultry in the IRW over about the last 50 years. In Figure 8-1, I show those same data, obtained from Dr. Fisher's considered materials. Also on the figure are depicted the changes during the same time period in the number of private colleges in the United States that grant PhD degrees and the total sales of grain world-wide. As is evident in this figure, all three of these variables (poultry, colleges, grain sales) increased steadily throughout the latter half of the 20th Century. Dr. Fisher's estimated numbers of poultry in the IRW are almost perfectly correlated with both the numbers of PhD-granting private colleges (Figure 8-2) and global grain sales (Figure 8-3). It would not be reasonable for me to conclude that increasing numbers of poultry in the IRW ***caused*** grain sales around the world to increase or ***caused*** more colleges that grant PhD degrees to spring up throughout the United States. Neither would I be justified in concluding that either global grain sales or number of PhD-granting colleges have caused an increase in poultry in the IRW. Nevertheless, over the period from about 1950 to 2000, there was a very close correlation (r^2=0.96) between annual estimates of the number of poultry in the IRW and the number of PhD-granting private colleges. There was an equally robust correlation (r^2= 0.96) between estimated numbers of poultry in the IRW and global grain sales.

If two variables (call them A and B) are correlated with each other, that correlation can occur because:

> A caused B,
>
> B caused A,
>
> A and B are both caused by some other variable (call it C) or combination of variables (call them C, D, and E), or
>
> A and B have nothing whatsoever to do with each other, but they both increased or decreased at the same time or in the same places.

As shown below, poultry house density in the IRW is itself correlated with several other variables known or suspected to be contributors of P to drainage waters. Any, all, or none of these variables may in fact be the true contributors of P to these streams analyzed by Dr. Engel. Dr. Engel and others claim that their observed correlations between poultry house density and stream water P concentration confirm their assumption that land application of poultry litter causes streams to have high P concentration. This claim has no basis in fact. Such statements represent a distorted view of statistical correlation. It would be equally valid for me to claim that the observed positive correlation between septic density and stream P concentration (presented below) confirms that septic discharge is responsible for the observed concentrations of total P in streams. Obviously (although perhaps not to Dr. Engel), neither claim can be substantiated by the statistical correlation in the data.

There are many other examples available on-line that illustrate the fallacy of Plaintiffs' consultants' assumption that correlation demonstrates causality. Below I list a few examples:

> *The more firemen fighting a fire, the more the damage will be. Therefore firemen cause damage.* This statement ignores the fact that large fires lead to greater fire-fighting response and also greater damage; thus, the number of firemen dispatched to the fire is correlated with the amount of fire damage.
>
> *As ice cream sales increase, the rate of drowning deaths increases sharply. Therefore ice cream causes drowning.* Such a statement ignores the time aspect of both swimming and ice cream consumption; both increase during hot summer weather.
>
> *Sleeping with one's shoes on is strongly associated with waking up with a headache. Therefore sleeping with one's shoes on causes headache.* Of course the more plausible explanation is that both the shoe retention and the headache are caused by intoxication.

Irrespective of the fact that Dr. Engel's correlations do not **demonstrate** the cause of P found in the streams in his high-flow study basins, there are numerous inconsistencies associated with his conclusions that he draws on the basis of his observed correlations. For the reasons described below, I believe that Dr. Engel's regression analyses that included buffers around his study basins are without merit. There are also problems associated with his interpretation of his regressions that did not include buffers around the study basins. He claimed to show significant correlations between poultry house density and stream P. As discussed above, this does not prove or demonstrate that poultry house density caused, or even contributed to, streams having higher P concentration. He also found (Appendix C, page C-3):

> ***Septic density is also shown to be a statistically significant predictor of stream phosphorus concentration for most of the data combinations.***

Nevertheless, Dr. Engel dismissed this finding and concluded that:

> ***…in areas with high poultry house development, human dwellings are also relatively high. This is not unexpected. Finally, an independent analysis of the total phosphorus loading expected from septic tanks in the watershed has shown these contributions to be negligible relative to the total mass loading in the systems (See Appendix G).***

I address the fallacy of his Appendix G mass loading argument in Section III.17 of this report. Dr. Engel's finding (which was not surprising to him, or to me) that human dwellings are high in areas where poultry house dwellings are high is important. Unfortunately, it was apparently not obvious to Dr. Engel that there are a variety of sources of NPS water pollution that occur in association with human habitation. There are many books, and perhaps many hundreds or thousands of journal articles, on this topic. Some of the most important of these NPS sources are described in Section III.6 of this report.

It is also noteworthy that Dr. Larson (November, 2008) analyzed Plaintiffs' ground water data in the IRW and found that poultry house density was not correlated with P, Zn, or Cu, each of which is claimed by the Plaintiffs to be associated with poultry litter. Obviously, there are many correlations, and demonstrated lack of correlations, in the analyses of the various experts and consultants in this case. None of them **prove** anything. Correlations can be used as one line of evidence in evaluating potential relationships between variables, but cannot be used as the basis for scientific decision making.

Dr. Engel found that some of these correlations were statistically significant, especially those that included a two-mile buffer. From this finding, he concluded that there was a cause and effect relationship between poultry house operations and P concentrations in IRW waters. As described by Dr. Chadwick (2009) and below, there are several critical problems with Dr. Engel's analyses and this conclusion, beyond the fundamental difficulty that his correlations do not prove anything.

First, Dr. Engel double-counted many poultry houses in his analyses. Several of his subwatersheds were sufficiently close to each other that a given poultry house was in many cases counted as occurring within two or three subwatersheds (Chadwick 2009).

Second, he assumed that some poultry litter might be hauled into a given subwatershed from a poultry operation outside of, but within a two mile distance of, that subwatershed. He therefore included in each buffered subwatershed poultry houses within two miles outside the subwatershed boundary. His rationale was apparently that poultry litter might be trucked into the study basins from outside the basin boundaries, from houses within a reasonable driving distance that he specified as two miles. As Dr. Stevenson acknowledged in his January 8, 2009 deposition (page 185-186), this 2 mile buffer that he and Dr. Engel applied to their study subwatersheds, would include individual poultry houses in more than one watershed, thereby resulting in a double-counting of some of the poultry houses. I do not accept or attempt to refute his claim that poultry litter is likely trucked into the study basins from a distance of two miles. But I do want to point out a critical flaw in the Plaintiffs' logic on this point. It failed to account for the fact that there was an equal likelihood that poultry litter originating inside, but within two miles of, the subwatershed boundary might be hauled ***out*** of the subwatershed for land application. By including poultry houses within two miles outside the boundary, but not excluding poultry houses within two miles inside the boundary, Dr. Engel once again exaggerated the number of poultry houses. In fact, by his counting method, there were 1,831 poultry houses inside the 14 study subwatersheds and their associated two-mile buffers, more than four times higher than the actual number of poultry houses (n=414) within the subwatersheds themselves (Chadwick, 2009). Thus, Dr. Engel is not applying his logic uniformly; rather, he is applying it selectively. This would be expected to bias his results. The same situation applies to application of the 2-mile buffer by Dr. Stevenson for his analyses. Actually, Dr. Stevenson acknowledged in his January 8, 2009 deposition (page 217) that he assumed that there was an equivalent exchange of poultry litter across the IRW boundary; what was coming in was assumed to equal what was going out. Yet, neither Dr. Stevenson nor Dr. Engel applied that same line of reasoning to their subwatershed boundaries. They only allowed for litter that might be trucked into the subwatersheds, with no allowance for the equal possibility that litter would be trucked out, thereby biasing their results. Furthermore, Dr. Stevenson stated in his January 8, 2009 deposition (page 220-221) that he relied on the 2-mile buffer for all of his analyses of poultry house density in his study subwatersheds. Therefore, none of those analyses by Dr. Sevenson are valid.

Third, as explained above, correlation does not demonstrate causality. Every good scientist knows this. To claim that a statistically significant correlation between number of poultry houses and stream P concentration demonstrates a cause and effect relationship is not accurate. To further compound this bias, Dr. Engel dismisses his observed significant correlations with septic density by concluding:

> ***that a true causal relationship between septic tanks and stream phosphorus concentrations does not exist. Rather, the perceived correlation between these variables is simply an artifact of the cross-correlation between residential dwellings and poultry house presence.***

Thus, it appears that Dr. Engel believes that he has the power to determine which of his statistically-significant correlations have meaning, and which are merely artifacts of cross correlation. However, he fails to share the insights that allow him to make these determinations, and there would be no scientifically defensible way of doing this, given the data that Dr. Engel presented.

Fourth, Dr. Engel deleted from consideration in his regression analyses subwatersheds that contained waste water treatment outflow contributions and appreciable amounts of urban land use (Figure 8-4). Thus, two of the most important sources of NPS pollution in the IRW (point source discharges from waste water treatment plants, and nonpoint source contributions from urban runoff) have been explicitly removed from Dr. Engel's analyses. This is not necessarily inappropriate, but it requires that his interpretations account for the fact that he is focusing his analyses on subwatersheds that have been selected to exclude two of the most important sources of P and fecal indicator bacteria in the IRW.

Fifth, and perhaps most importantly, Dr. Engel's estimate of poultry house density is itself correlated with other land uses and landscape conditions (Figures 8-5 through 8-7). As described below, many of the principal probable sources of NPS pollution that remain in the subwatersheds that he selected for his analyses are expected to be cross-correlated with his poultry house density numbers. Therefore, his poultry house density values are surrogates for a number of potential P sources in rural residential areas, including septic systems, cattle, erosion associated with roads, and other human activities. I show in Figure 8-5, correlations for total poultry house density (top panel) and for active poultry house density (bottom panel) versus septic density. The data were taken from Dr. Engel's database in his considered materials. Regression lines are drawn for data points coded as filled circles, after excluding subwatersheds that contained WWTP effluent discharge and/or more than 5% urban land use. He had deleted from his regression analyses two study subwatersheds that contained appreciable urban land use and/or a WWTP; I exclude from my regression lines these same two subwatersheds, plus a third that also contained more than 5% urban land use. Both regressions are statistically significant ($P<0.01$), illustrating that poultry house density is significantly correlated with septic density in Dr. Engel's non-urban subwatersheds. In Figure 8-6, I regress for these same subwatersheds poultry house density versus road density. Again, both correlations (active houses, $P<0.05$; and total houses, $P<0.01$) are statistically significant. Total and active poultry house densities are also significantly ($P<0.001$) correlated with cattle density in non-urban watersheds within the IRW. For this analysis, I was not able to use Dr. Engel's subwatersheds as the basis for the regression because he did not provide cattle density values for his subwatersheds and I had no way to calculate them. Rather, I used estimates of cattle density by county within the IRW from Dr. Clay together with calculations of poultry house densities for each county based on Dr. Engel's estimates of active and total poultry house locations.

Apparently, Dr. Engel believes that he is able to accept some correlations (e.g., poultry house density versus total P in stream water) as proof of a cause-effect relationship, whereas other correlations (e.g., septic density versus total P in stream water) are simply artifacts, and that his subjective judgment is an appropriate basis for deciding how a correlation should be interpreted. He makes no allowance for the likelihood that his observed correlation between poultry house density and stream water P is actually an artifact of the cross correlations that exist between poultry house density and various sources of NPS pollution that are associated with human habitation, including septic density, rural residential housing runoff, road density, cattle density, etc. As a consequence of these, and other (as explained by other Defendants' experts) errors, omissions, and misrepresentations, Dr. Engel's reported correlations between poultry house density and total P in stream water are completely without merit.

In the IRW, poultry houses are found where people who dwell in rural areas are found. Poultry houses are not found in the forest or generally in dense urban areas. Where people are found, there are many sources of P to streams, including soil erosion, malfunctioning septic systems, cattle access to streams and riparian zones, pet waste, and other livestock. Dr. Engel's poultry house density variable would be expected to capture all of these potential sources to some degree. Dr. Engel partly acknowledges this on page C-3, where he states that septic density was a significant predictor of stream P concentration and also that he found a strong cross-correlation between septic tanks and total poultry house density. He explains that:

> ***in areas with high poultry house development, human dwellings are also high. This is not unexpected.***

Dr. Engel neglects to say, however, that many of the various forms of NPS pollution would also be expected to be high in these same areas. Rather, he dismisses the importance of his observed correlation between poultry house density and stream P, based partly on his observation that:

> ***these correlations are not generally as strong as those associated with poultry house density within the 2 mile buffered area.***

Dr. Engel ignores the fact that his correlations with septic house density are actually as strong (five of six regressions statistically significant) as were his correlations with poultry house density without his arbitrary buffers (five of six regressions significant based on total house density; four of six regressions significant based on active house density; his page C-4). In addition, Dr. Engel cites his analysis presented in Appendix G as part of his foundation for dismissing the importance of septic systems relative to the total mass loading in the systems. As described in Section III.17 of this report, the total mass loading is not an appropriate statistic for discriminating among potential NPS sources. Mass loading within the watershed is only one part of a complex picture. In order for such loading to result in stream pollution, there must be transport mechanisms available with which to transport the pollutants from the ground surface to the stream water. Dr. Engel has not demonstrated the existence of such transport mechanisms, let alone quantified the amount of transport that actually occurs.

In sum, there is no basis for concluding that Dr. Engel's regression analyses demonstrate that poultry operations cause P pollution of streams in the IRW.

9. *Phosphorus and fecal indicator bacteria are generally not very mobile in soils; their presence in, or at the edge of, a field does not indicate that these variables are transported*

to a stream in sufficient quantity to have an appreciable effect on stream water quality. Plaintiffs' consultants fail to demonstrate that their measured concentrations of P and fecal indicator bacteria in litter, soil, or edge-of-field samples have any influence on measured concentrations of these constituents in stream waters. Plaintiffs' consultants do not provide fate and transport documentation for their assertion that constituents that might be present in poultry litter in a barn or on a field, or in ponded water at the edge of a field or in a ditch, ever actually move to a stream or to Lake Tenkiller in quantities sufficient to affect water quality in any appreciable way.

Much of the phosphate found in soil is adsorbed to soil particles or incorporated into organic matter. Because phosphate is tightly bound to soil particles, it is not easily leached out of soil and into drainage water (Pitois et al. 2001). This characteristic of P behavior is well known. Sharpley et al. (2003a, page 11) concluded that:

> ***Generally, the concentration of P in water percolating through the soil profile is low because of P fixation by P-deficient subsoils.***

Ritter (2001) concluded that:

> ***All forms of inorganic P in soils are extremely insoluble. Because of the high adsorptive capacity of P by clays, the Fe and Al oxides leaching of P to groundwater is rare. The situation where P leaching may occur is in well-drained, deep, sandy soils.***

Ritter (2001, page 151) went on to say:

> ***Phosphorus is adsorbed by soil particles, so loss of P in surface runoff is of greater concern than leaching.***

Irrigation, especially furrow irrigation, can significantly increase the P loss by both surface runoff and erosion. Furrow irrigation exposes unprotected surface soil to the erosive action of water movement (Sharpley et al. 2003a, page 12).

The propensity for both P and fecal bacteria to move from pasture to surface water is determined by a number of variables, including the loading rate of P and bacteria to the pasture, the elapsed time between loading and the occurrence of heavy rain, the intensity and duration of rainfall, the die-off rate of the bacteria in the field (which depends on such things as temperature, moisture, sunlight, and soil conditions), and the movement of water from the field into a stream. There is no *a priori* reason to expect that different species of bacteria will move in the environment in the same way, or at the same rate or that P will move at the same rate as any group of fecal indicator bacteria. The National Research Council (2004, page 173) concluded that the use of fecal bacteria indicators is based on the presumption that the indicators co-occur at a constant ratio with illness-causing pathogens. They went on to state that:

> ***This premise is flawed … Furthermore, upon leaving the intestinal tract, microbial indicators and pathogens degrade at different rates that are mediated by factors such as the resistance to aerobic conditions, ultraviolet radiation, temperature changes, and salinity… Several studies have also found that some indicator bacteria can grow outside the human or animal intestinal system*** *(several cited references)****, further confounding the correlation between pathogens and indicators.***

Thus, the National Research Council of the National Academy of Sciences concluded that the premise that fecal indicator bacteria move through the environment at a comparable rate to pathogenic microbes is flawed. Dr. Harwood relies on this same premise in her effort to link her purported biomarker to fecal indicator bacteria. There is no *a priori* reason to assume that the intact bacteria and/or the tiny pieces of DNA that Dr. Harwood (2008) identified as coming from *Brevibacterium avium*, or some previously unknown species that is closely related to *Brevibacterium avium*, would be expected to move in the same way or at the same rate as *E. coli* or any other species of bacteria. Neither is there *a priori* reason to believe that P, or any other chemical constituent, would be expected to move in the same way or at the same rate as Dr. Harwood's bacterium or her tiny pieces of DNA (her biomarker). Dr. Harwood recognized the importance of this complicating factor. In her Preliminary Injunction hearing testimony (Volume III, February 21, 2008 transcript, page 744), Dr. Harwood stated:

> ***We also have the question of there are things we don't know about the relative rates of transport of pathogens compared to indicator bacteria and pathogens compared to the biomarker.***

When asked whether the biomarker has a different life span in the environment than, for example, a chemical, she responded (transcript page 744):

> ***Well, a chemical might be expected to persist indefinitely until it gets used through biogeochemical cycling. Because bacteria are biological organisms, they have a certain amount of persistence time in the environment so they will not persist indefinitely over time.***

When asked about Dr. Harwood's previous deposition testimony regarding the fact that bacteria move at different rates through the environment, she testified (transcript page 769) that bacteria move at different rates:

> ***depending in part or in large part, I believe, on the physical and chemical factors that influence their movement***

She further testified that such factors can include temperature, location within the water column, presence of vegetation, the media through which the bacteria move, and the size of the spaces through which they are moving. Dr. Harwood was asked if she found two different species of bacteria in a field, whether she could assume that they would move at the same rates. Her response (transcript page 70) was:

> ***I wouldn't want to assume. I would want to test it.***

In this case, neither Dr. Harwood nor any of the other consultants for the Plaintiffs have offered evidence that they have tested differences in movement among different species of bacteria, differences in movement between P and any species of bacteria, or differences in movement between any species of bacteria and Dr. Harwood's DNA biomarker. The following exchange was recorded:

Q, ***In fact, as part of your work in this case, you did not study the movement characteristics of any type of bacteria in the watershed, did you?***

A. ***No. I did not.***

Q. ***Are you offering any opinion today as to the relative survival rates of the bacteria that you found in the watershed?***

A. ***No.***

Dr. Harwood concluded (page 755) that:

> ***…land application of poultry waste in the IRW is a major contributor to elevated indicator bacteria loads in the Illinois River watershed, in these waters (***Transcript of Preliminary Injunction testimony, Volume III, February 21, 2008, page 755***)***

She reached this conclusion using a weight of evidence approach that was based in part on her belief that there was a:

> ***…widespread and quantifiable presence of the poultry litter biomarker and the evident pathway in terms of its concentration gradient from the litter to the fields to the edge of field and then to surface water and groundwater samples…***

Dr. Harwood's belief that her purported biomarker, or the bacterium or bacteria from which it is derived, has been transported through the watershed along the pathway that she claims does not necessarily mean that *E. coli*, *Salmonella*, *Campylobacter*, phosphorus, or any other constituent (living bacteria or chemical) would have followed the same pathway, at the same rate, in sufficient time for the bacteria to remain viable, with comparable movement and retention in different parts of the watershed system. Thus, Dr. Harwood's biomarker cannot be assumed to represent movement of P, fecal indicator bacteria, or pathogenic bacteria within the IRW simply because Dr. Harwood found that biomarker at lower concentrations at the bottom of her pathway than she did at the top of her pathway. These patterns can be further complicated if the bacteria that are the source of Dr. Harwood's biomarker are able to reproduce in the environment. Dr. Harwood acknowledged in her July 18, 2008 deposition (transcript, page 17) that *E. coli* and enterococci have the ability to persist for months, and that they may actually multiply in some environments. She indicated that she had no evidence regarding whether the *Brevibacteria* that she identified through her PCR process might grow in the environment. The following exchange was recorded:

> Q. ***If the Brevibacteria did grow in the environment, how would that impact its correlation with indicator bacteria?***
>
> ***A. That's almost impossible to say…***

In addition to the problems with interpretation of Dr. Harwood's biomarker due to uncertainties concerning relative movement of bacteria and P through the watershed, there is also substantial concern about the species-specificity of her biomarker. The species that she identified as the possible or likely species, from which the biomarker was derived, has the specific name "avium"; that means "bird". Dr. Harwood tested three kinds of birds for the biomarker: poultry, ducks, and geese. She found it in all three. We don't know in how many other species of bird this species of bacteria may occur. There are over 300 species of bird in Benton and Washington Counties, Arkansas combined, including more than 30 species of ducks and geese (Arkansas Audubon Society 2008). Dr. Harwood tested only a very small percentage of the bird species that occur in the IRW. We have no idea in how many other species these bacteria may reside. We therefore don't know the sources of the bacteria that she found in her water samples. The bacteria may be derived from multiple bird species found in multiple locations throughout the watershed. Dr. Harwood's analysis assumes that they are all derived from poultry and that they are all deposited to pasture land. She provides inadequate data to document whether or not those assumptions are correct.

In general, both P and fecal indicator bacteria will be removed from water that moves down into the soil profile. This is because both tend to adsorb to soil particles. Transport of these constituents from pasture to stream occurs mostly as overland flow, which (on pasture land) is generally limited primarily to pasture areas that have particular characteristics. These are the areas along the stream channel, the areas that become flooded during heavy rains, and the areas that comprise ephemeral (temporary) streams. If a farmer is following BMPs, poultry litter will not be spread on soils that are near to streams or on soils that flood during heavy rains. Such BMP farming practices minimize the possibility of P and bacterial contamination of surface water. Additional practices that can reduce the movement of these constituents from field to stream include avoidance of litter spreading in advance of a rainstorm and maintenance of a vegetated buffer zone between litter-amended pasture and surface water. The former can be important because bacteria die over time on the field after litter spreading. The latter can be important because any surface runoff that does occur will be filtered by the surface vegetation in the vegetated buffer before the water enters a stream. Such filtering effectively removes some of the P and bacteria from the runoff. Thus, the mere presence of P or fecal indicator bacteria on the surface of an agricultural field does not mean that a nearby stream will be contaminated with either of these constituents. A transport mechanism is required, such as heavy rain in an area that is prone to overland flow. Various practices are available to farmers, and are in fact incorporated into existing guidelines governing nutrient management, with which to minimize or eliminate the extent to which such surface water contamination occurs.

Any standing water on, or immediately adjacent to, an agricultural field that has a source of P and fecal bacteria (for example cattle, other livestock, poultry litter) may (depending on hydrology) contain these constituents subsequent to heavy rain. This is not surprising. It is also not surprising that the concentration of either or both of these constituents in a puddle or ditch might be many times higher than the respective stream water standards. However, the occurrence of P or bacteria in standing water found in, or at the edge of, a field does not indicate that those constituents will be transported to stream water at all, or if indeed they are transported to a stream that they will be transported in quantities that will have a measurable influence on either the concentrations in the stream or whether that stream does or does not meet Primary Body Contact Recreation standards for fecal indicator bacteria or the total P standard applicable to Scenic Rivers in Oklahoma. In some cases, such field water does not reach a stream without first percolating down through soil, where bacteria can be removed via adsorption to soil. In other cases, some of that field water may actually enter a stream, but the volume of water that does so is too small to have a measurable impact on the concentration of bacteria in stream water. In order for P or bacteria in field runoff to be quantitatively important to a nearby stream, both the concentration of bacteria in the water AND the quantity of water flowing into the stream must be high enough that the load of bacterial input is high relative to the volume of water in the stream. BMPs routinely specify that one must be careful to identify locations where such transport is most likely to occur and then one must avoid application of poultry litter in those areas, especially in advance of rain.

Any P or fecal indicator bacteria that do reach a stream from a land-based source of these constituents can then be transported downstream. During that transport, some bacteria die and others settle to the bottom and are incorporated into the stream sediment, from which they can be re-suspended during high flow periods or where they may die or be consumed. Some P can also settle to the stream sediment, especially in ponded areas such as Lake Frances, located on the mainstem Illinois River in Oklahoma, near the Arkansas border. Thus, as you move downstream, the concentrations of both P and bacteria often decrease unless there are substantial additional source areas. This is an important point because it cannot be assumed that fecal indicator bacteria contributed to the Illinois River system in Arkansas will necessarily survive long and far enough to enter the sections of the river in sufficient numbers as to cause the concentration to exceed standards at the locations where most of the recreational use occurs.

Turner and Leytem (2004) developed extraction procedures to assess the chemical characteristics and potential behavior of P in the environment. Although they stated that phosphates in manures and runoff are correlated following recent manure land application, they also cautioned that phosphates can be strongly retained in soil if drainage occurs downward through the soil profile. In addition, they stated that:

> ***Hydrological factors, including the pathway taken by runoff as it leaves the field, must be considered when assigning the risk of phosphorus transfer from recently applied manure (Haygarth and Jarvis 1999).***

It has long been recognized that P is not very mobile in soils. In fact, Haygarth and Jarvis (1999) quoted a book by Sir John E. Russell from 1957 that described P as being “insoluble in water”, which resulted in it “staying in the surface soil apparently forever”. Although this statement was an obvious oversimplification, it serves to emphasize the fact that P is not very mobile in soils.

10. *The concentrations of P and fecal indicator bacteria in stream water are strongly dependent on water flow, such that concentrations tend to be much higher under high flow conditions as compared with low flow conditions. In addition, concentrations of fecal indicator bacteria in the IRW tend to be above geomean standards primarily in the smaller (those that I classify here as third order and smaller) streams, and less often in the larger (those that I classify here as fourth order and larger) streams. These patterns have implications regarding how P and fecal indicator bacteria data should be analyzed and interpreted.*

<u>Effect of Stream Flow</u>

The dependence of P and fecal indicator bacteria concentrations on stream flow and stream order is important for several reasons. First, there are fewer river recreationists during storm periods when flows are highest and fecal indicator bacteria concentrations are highest. Second, river recreation is focused mostly on the larger streams (Plaintiffs’ consultant Dr. Caneday Preliminary Injunction testimony), which tend to have lower concentrations of fecal indicator bacteria. Thus, most recreationists are not exposed to the concentrations of fecal indicator bacteria found to occur during high flow events or in the small streams. Third, the measured concentrations of fecal indicator bacteria and P in stream water are heavily dependent on the flow conditions at which the samples were collected. This makes it difficult to document changes over time or to identify locations where water quality standards might be violated, especially if samples are collected such that they are not representative of the normal range of flow conditions or if the frequency of sampling at high versus low flow changes during the monitoring period.

Evaluation of bacteria concentration data for river or stream water must consider the influence of stream flow on bacteria sources. The concentration of FCB or *E. coli* in water within watersheds containing mixed land use varies directly with flow such that concentrations tend to be higher when flow is high and concentrations tend to be lower when flow is low. It is well known that this occurs essentially everywhere. The reasons why this is true have to do with the mechanisms by which fecal bacteria from all sources move from the landscape to flowing water. High flow provides the opportunity for some waste water treatment facilities to become overloaded with runoff water, creating a sewage bypass, and also provides the transport mechanism to move bacteria from all land-based sources to the water. This pattern is well illustrated using data collected by the USGS (Figure 10-1), which show that the concentrations of FCB and *E. coli* in the Illinois River near Tahlequah are generally below both the respective geomean standards and the respective individual (or 10% of individual) sample standards when river flows are low. However, fecal indicator bacteria samples are often above the standards when flows are high, especially when they are above what I define here as “high flow” to include flows above the 70th percentile of long-term (January 1980 to May 2007) daily average flows recorded by USGS at this site. In other words, 30% of the daily average flows are above the value used to discriminate between high flow and other than high flow, and 70% are below it. The shaded portion of the panels in this figure indicates data collected during high flow periods; nearly all of the bacteria concentrations above the standards at this site, which is located just upstream from Lake Tenkiller, occurred during high flow.

Therefore, one should not try to evaluate changes over time (trends) in fecal indicator bacteria concentration without taking flow into consideration. Furthermore, bacteria concentrations in the Illinois River tend to be above standards primarily at times when one would expect minimal river recreation to be occurring (during rainy periods with high river flows).

In Figure 10-2, I show USGS data from the Illinois River near Tahlequah, OK, showing changes in the geomean concentration of FCB, *E. coli*, and total P over time. At first glance, it might appear that something happened after 1999 that dramatically increased the level of fecal indicator bacteria and P concentrations in the Illinois River. The geomean concentrations for all three constituents increased dramatically after 1999. That first impression is incorrect. The USGS changed its sampling procedures in 1999, such that fixed interval sampling was replaced by sampling that was intended to capture storm events. Thus, the data collected prior to 1999 are not comparable with the data collected after 1999 unless flow is considered. The effect of flow on fecal indicator bacteria and P concentrations can be illustrated by examining the data at this site, expressed as individual sample occurrences, where each sample is coded according to river flow at the time that the sample was collected (Figure 10-3). For this analysis, high flow again represents flows in excess of the long-term 70th percentile flow value; moderate flow represents flows between the 30th and 70th percentiles; and low flow represents flows below the 30th percentile of the long-term flow record.

The concentrations of fecal bacteria indicators in the Illinois River are strongly related to water flow, such that concentrations of bacteria above the geomean standards occur primarily during periods of high flow. Under low flow conditions, when I would expect that most on-river recreation (i.e., canoeing) occurs, FCB and *E. coli* tend to be below the geomean standards

(Figure 10-2). This has important implications regarding how surface water fecal indicator data should be analyzed and interpreted.

Figures 10-2 and 10-3**,** showing different representations of the same data, collected by the same agency, from the same location illustrate a number of important points. Contrary to the highly misleading graphic offered by the Plaintiffs in the Preliminary Injunction hearing, purported to indicate an increasing trend over time in bacterial concentrations in the Illinois River, there is no indication in the USGS data that fecal indicator bacteria or total P concentrations at this site have increased over time. Rather, the large differences in concentrations recorded during the various years are mainly determined by the number of high flow samples that were collected. For years during which many high flow samples were collected, the bacteria concentration values (including the geomean of the values) were relatively high. For years during which few high flow samples were collected, the bacteria and total P concentration values were relatively low. Many more samples were collected by USGS during high flow conditions during the years post-1998 (Figure 10-4). Any representation by the Plaintiffs that such data reflect a pattern of increasing fecal indicator bacteria or total P concentration over time is not accurate.

Point sources of water pollution, such as WWTPs, contribute constituents, including P, to stream water under all flow regimes. During high flow periods, it is also possible for constituents such as P and fecal indicator bacteria to move as nonpoint source contributions from some land locations to streams. Point sources can also contribute to concentrations in stream water under high flow conditions because high flow can re-suspend P that had been deposited in the stream sediments when flows were low. This mechanism was documented by Haggard et al. (2001) in Spavinaw Creek, Arkansas. They concluded that:

> ***the P adsorbed to benthic*** [stream bottom] ***sediments may be resuspended into the water column and transported downstream during storm runoff events… Perhaps the most important finding in this study is the pronounced impact that Columbia Hollow [***WWPT plant***] has on P retention in Spavinaw Creek. P retention efficiency in Spavinaw Creek was reduced by a factor of 30 below Columbia Hollow***

Similarly, Haggard et al. (2003b, page 191) concluded that:

> ***Almost half of TP transported in streams during storm events may be resuspended from bottom sediments (Svendsen et al. 1995). Release or resuspension of P associated with stream sediments in the Illinois River may be a critical source because this stream receives P inputs from several wastewater treatment plants in the headwaters."***

Ekka et al. (2006, page 389) stated that:

> ***During storm events, dissolved and total P transport may be influenced by resuspension of point sources of pollution. Suspended sediments in streams affect dissolved P equilibrium between water and benthic sediments (House et al. 1995) and likely impact dissolved P concentrations occurring during surface runoff events in streams"***

Pickup et al. (2003), in a USGS report on P in the IRW, concluded that P concentrations generally increased with runoff, and they offered as possible explanations for this: P resuspension from the stream bed, stream bank erosion, and the addition of P from nonpoint sources. In contrast to the interpretation of Pickup et al. (2003), one might erroneously conclude from the reports of Plaintiffs' consultants that resuspension from the stream bed, stream bank erosion, and a variety of NPS pollution sources are unimportant and nearly all NPS P is derived from poultry litter.

There are numerous temporary sinks for P in stream systems. These include P adsorption to sediment, various impoundments, and uptake from the water column by microbes and aquatic plants (cf., Haggard et al. 2004). As a consequence, some of the P that is contributed by point sources during low flow conditions can be stored in the sediment and biological communities and then remobilized into stream water if the P sources become reduced or during high stream flows (Haggard et al. 2004).

Recreational activities in the IRW (described by Plaintiffs' consultant Dr. Caneday (2008) and Defendants' consultant Dr. Dunford (2008)) are primarily those covered by secondary body contact recreation, such as wading, canoeing, boating, and fishing. The Illinois River is primarily a floating river, rather than a swimming river. The primary body contact recreation standards for fecal indicator bacteria apply to full immersion, which does occur in the IRW, but which is generally infrequent and short-lived (Dunford 2008). Secondary standards are generally five times higher than primary standards (Gibb 2008, page 11).

<u>Effect of Stream Order</u>

Streams within the watershed are commonly classified according to Strahler stream order, which reflects the relative size of the various streams. The smallest tributaries in the upper portions of the watershed are first order. As the first order stream flows downhill, it combines with other first order streams. Once two first order streams combine, they form a second order stream. The process continues in a downstream direction to higher orders (Figure 10-5). In the IRW, most streams range from first order to sixth order (Figure 10-6) based on the National Hydrography Dataset; a short segment of the Illinois River is classified here as seventh order below the confluence with the Baron Fork. First order streams tend to be very numerous and very small. In general, they were not sampled by Plaintiffs' consultants in their stream sampling efforts for this case. In Figure 10-6, I show the locations of streams within the watershed that are second order and larger. The rafting section of the Illinois River is sixth order according to this scheme.

It can be useful to break down the sampled streams within the watershed into stream order classes, because some conditions vary with stream order. For example, the geomean *E. coli* concentrations measured by Plaintiffs' consultants in the IRW tend to be higher for the smaller (lower order) streams as compared with the larger streams. The geomean from Plaintiffs' database of the measured *E. coli* concentrations in fourth, fifth, and sixth order streams are below the geomean standard for primary body contact recreation (Figure 10-7). I expect most of the stream recreation to occur on these larger streams, and they generally have lower *E. coli* concentrations than do the smaller streams where I expect less stream recreation to occur.

11. *In order for land applied P to have an ecological impact on a stream, it must be physically transported from the site of land application to the stream. P and fecal indicator bacteria are not uniformly contributed to streams via runoff from pasture lands, but rather are disproportionately contributed from hydrologically active areas. These are portions of the landscape that contribute most of the overland flow to streams during rain storms. Overland*

> *flow is important as a potential vehicle for transporting P and fecal indicator bacteria to streams because runoff that follows this flow path has relatively little interaction with soil particles, which can adsorb P and fecal indicator bacteria, thereby preventing them from entering the stream. One cannot* ***assume*** *that constituents such as P and bacteria are simply washed across pastures and into streams during rain storms. For the most part, runoff does not follow such a flow path. Runoff hydrology is far more complex than that.*

Direct runoff is the water that moves from the land surface to the stream in response to a storm. It can have several components. Hortonian overland flow is surface runoff produced at the ground surface when the rainfall intensity exceeds the infiltration capacity of the soil. This type of runoff (also called "infiltration-excess runoff") can be important on clay soils that have limited infiltration capacity. Hortonian overland flow can also increase where land management practices decrease the infiltration capacity of surface soils via animal or machinery-induced compaction, overgrazing, and/or crusting of the soil surface. Another type of overland flow, called saturation-excess overland flow, occurs when the soil surface in a particular area within the watershed becomes totally saturated, and additional precipitation is unable to infiltrate into the soil. Saturation-excess overland flow often occurs in proximity to a stream, and often occurs as water comes up from deeper soil horizons or by lateral movement of soil water. Throughflow is water that infiltrates rapidly into the soil and then moves laterally.

The pathway followed by drainage water has a large influence on the extent to which various constituents will be transported from the soil surface to a stream. For example, throughflow provides proportionately more contact between drainage water and soil surfaces; overland flow provides proportionately less contact with the soil, but does provide contact with vegetation at the ground surface. The amount of contact between drainage water and soil influences the movement of many constituents, including P, in that water.

Heathwaite et al. (2000) described the hydrological pathways of P transport from agricultural fields in an attempt to account for their significance in contributing P from agricultural land to stream waters. At the hillslope scale, the principal trigger for runoff is the amount, duration and intensity of rainfall; other important factors include antecedent soil moisture, topography, and soil hydrologic conductivity. Heathwaite et al. (2000) describes saturation-excess overland flow as:

> ***Topographically-driven from spatially and temporally dynamic variable source areas (VSAs).***

It is widely believed that a large component (perhaps up to 90%) of the P load in receiving waters is derived from only a small percentage, perhaps about 10%, of the watershed (Pionke et al. 1997, Heathwaite et al. 2000).Typically, most of the pasture area does not contribute much overland flow, and therefore does not contribute much P, to the stream.

P is not very mobile in soils and tends to remain near the point of application adsorbed to soil particles (Novotny and Olem 1994, page 335). In contrast, other constituents, such as chloride for example, are highly mobile in soils and tend to move in solution along with drainage water. Clay and organic particles have a high sorptive capacity for many chemicals, including phosphates, and act as carriers for contaminant transport (Novotny and Chesters 1981, Novotny and Olem 1994, page 295). For that reason, erosion of clay particles can be an important source of P to stream waters. Erosion is commonly associated with dirt roads, roadside ditches and culverts, disturbed soils (e.g., construction sites, areas frequented by livestock, cultivated agricultural lands and row crops), and unstable stream banks. Plaintiffs' consultants did not evaluate the extent to which erosion contributes P and other constituents to streams in the IRW.

Enrichment of stream water by nutrients, fecal indicator bacteria, or other constituents is dependent on three fundamentally different factors. The first is the quantity of the constituent available in the watershed. The second is the location of the source areas that are enriched in that constituent relative to flowing stream waters. The third and final key factor is the presence of a transport mechanism. Plaintiffs' consultants generally focused only on the first of these three factors. Large quantities of P within the watershed at variable distances from the stream network can only pose a risk to water quality if there is a pathway by which to transport substantial quantities of that P from the terrestrial environment to the stream. As discussed more fully in Section III.19 of this report, current land management recommendations and regulations are aimed at all three of these key factors. Water quality protection is largely focused on identification and subsequent remediation of areas with high potential for appreciable contaminant sources, located in close proximity to a stream, with high potential for transport to the stream (Ritter and Shirmohammadi 2001, page 95).

In the IRW today, pursuant to the laws of Oklahoma and Arkansas, land application of poultry litter is constrained to fields where site-specific nutrient management plans permit land application of poultry litter and to portions of those fields that are not prone to surface transport because they do not routinely flood, are not frozen at the time of litter application, and are not located in close proximity to a stream.

Both the amount of P applied to a field and the associated soil P content provide incomplete assessment of the potential for P loss from a site because they do not account for processes that control the transport of P in surface runoff or subsurface flow (Kleinman et al. 2000, Sharpley et al. 2001). Adjacent fields can have similar soil P concentrations, yet have substantially different P loss potentials (Sharpley and Tunney 2000, Sharpley et al. 2001). Hydrological factors, including the pathway followed by water as it leaves a field, must be considered when evaluating the risk of P transfer from field applied manure to stream water (Turner and Leytem 2004, page 6106). When drainage occurs downward in the soil profile subsequent to field application of manure, P can be strongly retained in the soil. Thus, in determining the possibility of P transfer from field to stream, the water flow path is of critical importance.

Not all areas within a watershed, and not all areas within a pasture, will generate surface (overland flow) runoff, and consequently have an enhanced ability to transport NPS pollutants to streams. The areas that routinely produce surface runoff are called hydrologically active areas; the remainder of the watershed, which is not hydrologically active, contributes mainly to interflow and base flow, which are characterized by markedly increased contact of drainage water with soil particles to which P and fecal indicator bacteria can become adsorbed. Thus, interflow and base flow hydrological flowpaths favor removal of P and fecal indicator bacteria from drainage water. The areas within the watershed that tend to have the highest hydrological activity are the impervious areas (covered soils [such as for example with asphalt, concrete, or structures] with little infiltration of rain water), followed by clayey soils having low permeability, frozen soils with high moisture content, soils with high groundwater table (areas that flood and are subject to saturated overland flow), and highly compacted soils (Novotny 1995, p. 92). Impervious areas are mainly found in urban environments and other built up areas. Highly compacted soils also predominate in urban environments, including lands that are under construction or other development; they can also occur in areas with logging (compaction from heavy equipment), or areas with dense concentrations of livestock (compaction from weight of animals).

Storm runoff is typically generated primarily from a small portion of the drainage area, from the portions of the watershed that are hydrologically active. The fraction of the total precipitation volume that does not contribute to direct runoff, but rather functions to wet the soil at the beginning of the rainstorm, is stored in depressions (as depression storage), infiltrates into the soil and subsequently contributes to deep base flow, or is evaporated or transpired back to the atmosphere. These concepts are important because the pathway followed by water as it moves across the landscape and into the stream can have large impacts on the extent to which constituents such as P and fecal indicator bacteria are retained on the soil versus transported into the stream. Where drainage water interacts extensively with soil, much of the P and bacteria are removed from the water and adsorbed to the soil. Where there is little interaction of water with soil, for example during saturated overland flow or Hortonian overland flow, there is greater opportunity for these constituents to be transported from the land surface to a stream. The areas within pastures having high hydrological activity, and therefore those prone to overland flow, represent pasture conditions that are specifically targeted by current litter spreading regulations. Such litter spreading regulations were crafted with these hydrological flow paths in mind, and are intended to limit the transport of constituents such as P and fecal indicator bacteria from pasture to stream. In assuming for many of their arguments that P and fecal indicator bacteria move from pasture to field, with no consideration of the importance of transport processes and pathways, Plaintiffs' consultants fail to consider the body of scientific data and understanding that provides the underpinning for such Federal and State regulations.

It appears from page 6-4 of his report that Dr. Olsen has some understanding of the importance of flow paths to pollutant transport. He states that:

> ***if sufficient rainfall occurs in a short enough period of time, runoff is produced (i.e., not all the water can be taken up by the soil and it runs off the field).***

Dr. Olsen fails to acknowledge, however, the importance of this issue with regard to the contribution of constituents to streams from various land surfaces. Based on the rainfall, soil conditions, and topographical patterns in the watershed, it is the hydrologically active areas that generate most of the runoff. Nevertheless, neither Dr. Olsen, nor the other Plaintiffs' consultants, assessed hydrological conditions during rain events on any field in the IRW to which poultry litter had been applied.

Sharpley et al. (2001) concluded that:

> ***Generally, most P exported from agricultural watersheds comes from only a small part of the landscape during a few relatively large storms, where hydrologically active areas of a watershed contributing surface runoff to streamflow are coincident with areas of high soil P (Pionke et al. 1997, Gburek and Sharpley 1998).***

For that reason, control of P loss must focus on the critical source areas, which are dependent on transport and site management factors. Sharpley et al. (2001) went on to say that:

> ***areas contributing P to drainage waters appear to be localized to soils with high soil P saturation and hydrological connectivity to the drainage network***

> ***(Schoumans and Breeuwsma 1997). Therefore, soil P levels alone have little meaning vis a vis P loss potential unless they are used in conjunction with estimates of potential surface runoff and subsurface flow .***

Weld et al. (2001) concluded that:

> ***Threshold soil P criteria will be of limited value unless they are integrated with site potential for runoff and erosion.***

In claiming that the application of poultry litter on pasture lands in the IRW would necessarily contribute large amounts of P to streams within the watershed, the Plaintiffs are essentially ignoring both the threshold P criteria and the site potential for runoff and erosion. The threshold criteria for the IRW are specified within current litter application regulations. The Plaintiffs emphasize their claim that some soils within the IRW have P concentrations higher than the criteria, but ignore the fact that farmers are no longer allowed or expected to spread litter on those fields that have relatively high soil P. In Oklahoma, the Oklahoma NRCS Code 590 prohibits land application of poultry litter to soils that have soil test phosphorus (STP) above 300 pounds per acre, whereas Arkansas offers a sliding scale based on slope and alum treatment of litter (Clay 2008). In many of their arguments, the Plaintiffs ignore altogether the potential for runoff and/or erosion. They simply assume that P added to a pasture via land application of poultry litter will enter a stream. No analyses are performed to evaluate the likelihood that such transport of P from field to stream actually occurs in the IRW or in what quantities it might occur. No allowance is made for the fact that required nutrient management plans consider the STP value for the field as part of the basis for determining appropriate litter application rates. Some of these issues are illustrated in the photographs shown as Figure 11-1.

The main factors that control the transport of P in agricultural areas are erosion, surface runoff, subsurface flow, and distance or connectivity of the site to the stream channel (Sharpley et al. 2001). Whereas erosion is commonly very high in areas occupied by row crops, it is much less common in pasture areas. Pastures can, however, contribute substantial amounts of erosion where livestock are concentrated, mainly because livestock trampling can eliminate some or all of the ground vegetation, especially in loafing areas and other areas frequented by livestock. This is particularly problematic in streamside riparian areas that are frequented by cattle unless riparian fencing is installed. In pasture areas, erosion is more commonly derived from stream banks (especially those accessible to livestock) and from road surfaces and associated ditches. Thus, erosion in portions of the landscape dominated by pasture areas is largely an issue of animal and road management, not poultry litter management.

Some surface runoff may occur at some locations in a watershed but not actually reach a stream channel (Gburek et al. 2000b, Sharpley et al. 2001). This can be the case for areas of surface depressions on a field or for ditches associated with fields, roads, or both. Such a pattern may have occurred with ponded water or roadside ditch water sampled by Plaintiffs' consultants in their edge-of-field sampling effort. However, because Plaintiffs' consultants did not bother to track the movement of such water down-gradient from their sample collection locations, it is unknown how prevalent that pattern might be in the IRW.

Critical source areas or "hot spots" of potential P loss from soil to stream are most frequently located near the stream channel (Weld et al. 2001). This is likely the main reason why litter application regulations require a setback from stream channels when applying poultry litter on pasture land. The stream setback, plus the requirement that litter not be spread on areas that frequently flood, are intended to minimize the possibility that poultry litter might be applied to one of these "hot spots". Gburek (2000a) concluded that:

> ***A comprehensive phosphorus-management strategy must do more than simply focus on the phosphorus status of the watershed; it must also incorporate the flow system linkages. Specific control measures implemented with a phosphorus-management effort will reduce losses from a watershed most effectively if they are targeted to critical source areas (CSAs), specific identifiable areas within a watershed that contribute most phosphorus that is exported …***

According to Ritter and Shirmhammadi (2001, page 102), the most important variables that influence runoff include rainfall amount and duration, soil texture, vegetative cover, and pre-event soil moisture. Runoff is highest with intense rainfall in large amounts, on fine-textured (high clay content) soils, with little vegetative cover, and high soil moisture in advance of the storm.

Infiltration into the soil of an agricultural field is highest when the field is unharvested, intermediate if it is harvested, and much lower if fallow. For example, Novotny and Olem (1994, page 112) reported infiltration rates after one hour of about 7 cm/hr for an unharvested agricultural field, 6 cm/hr for a harvested field, and only 4.3 cm/hr for a fallow field. Novotny and Olem (1994, page 130) presented an isopluvial map of the United States showing the once-per-year, one-hour long rainfall amounts. For the location of the IRW, this amount was 3.5 cm/hr (1.4 in/hr). This is only half the infiltration rate for unharvested agricultural land reported by Novotny and Olem (1994).

For the reasons described above, not all areas within a watershed generate surface runoff and the diffuse pollution that can be associated with it (Novotny and Olem, 1994, page 142). Areas with high surface storage, such as flat cropland, and soils with high permeability, often generate surface runoff only during extreme storms (Novotny and Olem, 1994, page 143). It is generally recognized that the abatement of NPS pollution should be focused on precipitation events that are frequent, typically medium magnitude storms with rainfall amounts in the range of 0.5 to 1.5 inches, which would occur several times each year, rather than rare, large storms (Novotny and Olem, 1994, page 129). In the general area of the IRW, the storm frequency return interval for a two-year 24-hour storm is about 4.1 inches of rain; the rainfall amount for a ten-year 24-hour return interval storm event is about 6 inches of rain (USDA NRCS Technical Release 55, TR-55). Dr. Fisher testified at deposition (September, 2008, transcript page 633) for this case that a large storm in the IRW entails about 2 inches of rain.

Reduction in the amount of P loss from agricultural land to streams depends on control strategies that focus on the critical areas within the landscape. These are defined by the intersection of two major components of P movement: source and transport. As described by the USDA Agricultural Research Service (Sharpley et al. 2003a):

> ***To cause an environmental problem, there must be a source of P (that is, high soil levels, manure or fertilizer applications, etc.) and it must be transported to a sensitive location (that is, for leaching, runoff, erosion, etc.). Problems occur where these two come together. A high P source with little opportunity for transport may not constitute an environmental threat. Likewise, a situation where there is high potential for transport but no source of P to move is also of***

> ***little threat. Management should focus on the areas where these two conditions intersect. These areas are called 'critical source areas'.***

This concept is illustrated schematically in Figure 11-2, redrawn from Sharpley et al. (2003a). This is a critical concept, and one that has been completely ignored by the Plaintiffs in this case. For controlling P movement from pastures to streams, an integrated approach is needed that incorporates the principles that provide the foundation for Figure 11-2. Pastures differ from one another in terms of both the source and the potential for transport. Within an individual pasture, there are also major differences in transport potential. To be effective, strategies aimed at reducing P inputs to streams must consider such variability across the landscape. P Indices attempt to incorporate such factors (Sharpley et al. 2003a), as do existing guidelines and regulations governing land application of poultry litter in Oklahoma and Arkansas. Nevertheless, with the exception of flawed (See Bierman 2009) GLEAMS modeling, Plaintiffs' consultants did not provide any analyses of transport potential on individual fields and made no attempt to identify any pasture areas in the IRW where source and transport potential intersect. They simply ignored the results of recent research.

Sharpley et al. (2003a) went on to state:

> ***…adjacent fields having similar soil test P levels but different susceptibilities to surface runoff and erosion, due to contrasting topography and management, should not have similar P management recommendations. Also, it has been shown that in some agricultural watersheds, 90 percent of annual algal-available P export from watersheds comes from only 10 percent of the land area during a few relatively large storms (Pionke et al. 1997).***

For these reasons, it is irresponsible to treat all pasture areas as having the same, or similar, potential for causing movement of P from pasture to stream (as Plaintiffs' consultants suggest in their effort to eliminate land application of poultry litter in the IRW). Such an approach is contrary to the body of scientific literature developed over the last two decades. In order for a nutrient control strategy to succeed it must target the areas most likely to actually contribute nutrients, not penalize all land owners and land areas under the incorrect assumption that they definitely contribute appreciable P to runoff simply because they fertilize their fields with poultry litter.

Sharpley et al. (2003b, page 138) stated:

> ***Generally, most P exported from agricultural watersheds derives from only a small part of the landscape during a few relatively large storms…To be effective, risk assessment must consider "critical source- areas" within a watershed that are most vulnerable to P loss in surface runoff*** (Gburek et al. 2000b)

The agricultural research community is now taking P management to the appropriate next level by:

> ***…defining, targeting, and remediating source areas of P where high soil P levels coincide with high surface runoff and erosion potentials… Conventionally applied remediations may not produce the desired results and may prove to be an inefficient and costly approach to the problem if this source-area perspective to target application of P fertility, surface runoff, and erosion control technology is not used."*** (Sharpley et al. 2003a, page 24)

Plaintiffs' consultants failed to recognize or ignored the current science on these issues.

Researchers know that there are reasonably well-defined "hot spots" that constitute the primary source areas for P and fecal indicator bacteria contributions from pastures to streams. It is not known what percentage of the pasture land area in the IRW may actually pose a high risk of P transport to streams. Plaintiffs' consultants did not perform such an analysis, and they failed to compare any of their GLEAMS model output to field-scale data collected in the IRW. They didn't even compare their field-scale model output to their edge-of-field data, perhaps because they did not have a good understanding of what their edge-of-field data actually represented. See further discussion of this in Section III.7.

A screening analysis using a P site index was developed and evaluated on seven farms in Delaware by Leytem et al. (2003). Although the authors concluded that additional validation remained to be performed, the results suggested that the vast majority (78%) of the fields evaluated were in the low risk category for contamination of stream water.

Runoff refers to the total loss of water from a watershed by all surface and subsurface pathways (Sharpley et al. 2003a). This includes overland flow and shallow horizontal flow that eventually returns to the surface; together these constitute surface runoff. Runoff is not uniform across the landscape. Surface runoff from one field, or a portion of one field, can enter a ditch or stream, flow into another field, percolate down into the soil, or flow into an agricultural pond. Such runoff may or may not directly enter the stream system. In order to determine the potential for runoff from a given field to impact the water quality of the stream system, one must evaluate not only the extent to which overland flow occurs, but also the connectivity of the field to the stream system. Plaintiffs' consultants did not undertake to determine this, either for individual fields or for their edge-of-field samples.

As discussed more fully in Section III.19 of this report, current national and also Oklahoma and Arkansas State guidelines and regulations discourage or prohibit the spreading of poultry litter on pasture lands in the IRW in areas likely to be hydrologically active and at times when runoff is most likely to occur, thereby minimizing the possibility of stream water contamination. These guidelines and regulations were explicitly designed for the purpose of minimizing the possibility of NPS pollution of streams from the spreading of poultry litter on pasture lands. I am not aware of any comparable restrictions on cattle grazing; in much of the IRW, cattle appear to have free access to streams and to streamside areas.

Dr. Fisher stated in his September 4, 2008 deposition (page 633), when asked:

> Q. ***And I think you testified earlier, if you get a lot of rainfall, you'll get runoff. What is a lot of rainfall?***
>
> ***A. More than two inches in 24 hours. I think that's kind of a rule of thumb around here.***

It is noteworthy that the available data indicating overland flow transport of P in experimental studies were typically collected with a minimum of 2 inches in one hour, rather than in 24 hours. It seldom rains with such intensity in the IRW. Rainfall simulation studies have been conducted to quantify P movement from soil to runoff water, but such studies typically employ rainfall intensities that are higher than normally occur during rain storms within the IRW. For example Kleinman et al. (2002) applied 7 cm/hr (2.8 inches per hour) artificial rain and measured P flux in experimental boxes. Butler et al. (2006) studied sediment and P export to streams from riparian areas with different levels of grazing disturbance subsequent to 1 hour of simulated rainfall at an intensity of 7 cm/hr. Similarly, experimental studies of fecal indicator bacteria movement from pastureland typically involve artificial irrigation at levels equal to or greater than 5 cm/hr (cf., Young et al. 1980, Coyne et al. 1995, Coyne et al. 1998).

Runoff experiments conducted by Daniel et al. (1995) using multiple simulated rainstorms and two rainfall intensities (5 and 10 cm/hr; 2 and 4 inches per hour) showed that the proportions of applied litter constituents lost in runoff from their 6 m-long experimental plots depended primarily on rain intensity. At the 5 cm/hr (2 inches per hour) intensity, litter constituent losses were generally low. However, at the 10 cm/hr intensity, total P losses were as high as 7.3%.

Rainfall intensity in the IRW is seldom as high as 2 inches per hour. Over the period of record at two rainfall monitoring stations within the watershed, such high rainfall intensity was recorded at each site only six times over a period of about 40 years. At these two rain monitoring stations, rainfall intensity above 1.7 inches per hour only occurred during one tenth of one percent of the hours for which rain was collected (Table 11-1**)**.

The abatement of NPS pollution should be focused on rain events that are frequent, typically of medium magnitude, with rainfall in the range of 0.5 to 1.5 inches, rather than large rare storms (Novotny 1995). Storms of medium magnitude would be expected to occur several times each year.

The majority of the runoff losses documented by Daniel et al. (1995) occurred during the first simulated rainstorm subsequent to litter application. Runoff quality approached background levels after relatively few (two to five) simulated rainstorms.

Thus, for pasture areas other than those which are hydrologically active, I do not expect that much P will be contributed by overland flow to streams under the more typical rainstorm conditions. This observation allows for flexibility in land management, while protecting water quality. According to the SERA-17 position paper on P indices (Radcliffe and Nelson 2005):

> ***Phosphorus-Indices generally identify only relatively small numbers of fields within watersheds as needing improved management of P, allowing producers to continue with their normal practices outside of these critical source areas (Leytem et al. 2003). Flexibility in management is a key asset to implementation of P-Indices…P-Indices allow producers or other land users to select from among strategies that will reduce the risk for P loss, including changing the method and/or timing of fertilizer or manure application, changing crop rotations and tillage practices to reduce erosion, or installing vegetated buffers or application setbacks to increase flow distances. This flexibility will help the producers search for the best methods to maintain profitability while protecting the environment."***

Dr. Olsen set out to collect edge-of-field samples of runoff water using pre-buried sample collection tubes at locations where surface runoff was expected. Eventually, Dr. Olsen realized that it proved difficult for him to reliably identify locations where sufficient runoff volume could be collected. It appears that he was operating under the naïve assumption that rainfall would uniformly generate overland flow that he could then collect in his sample tubes. This is simply not how it works.

Dr. Fisher correctly stated on page 50 of his report that:

If sufficient rainfall occurs in a short enough period of time, runoff is produced

Nevertheless, Dr. Fisher neglected to identify at what level rainfall would be considered to be sufficient.

As described above, it is important to consider the differences between runoff that moves across the pasture surface as overland flow and runoff that moves through the soil, where P fixation can occur. It is also important to consider that rainfall seldom falls with sufficient intensity to produce overland flow in many areas, especially where the soils are not clay type soils.

Dr. Engel cited a number of experimental studies that demonstrated P movement as overland flow from small experimental plots or soil boxes subsequent to application of poultry litter or other manure source. But Dr. Engel failed to acknowledge that these studies generally applied artificial irrigation at rainfall intensities that exceed rainfall amounts regularly experienced in the IRW. Radcliffe and Nelson (2005), in describing the position of SERA-17 on the topic of predicting P losses at the watershed and edge-of-field scale, stated the following:

> ***Many of the datasets used for the development of models and study of P transport mechanisms have been produced under simulated rainfall (Edwards et al. 1995, Sauer et al. 2000, Kleinman et al. 2002)… the predictive relationships developed from simulated rainfall are not always directly transferable to natural rainfall conditions (Cox and Hendricks 2000). Because of the differences between P losses observed under simulated rainfall vs. natural rainfall, models should be validated with datasets derived from natural rainfall studies.***

Plaintiffs' consultants have not done that.

Neither have Plaintiffs' consultants provided any clear evidence that spreading of poultry litter on pasture lands, given the current guidelines and regulations, actually contributes any appreciable amount of P to streams in the IRW.

In addition, many studies that have attempted to quantify contributions of P from manure-amended pasture lands are complicated by the presence of cattle or other grazing animals on those pastures. Current litter application guidelines and regulations are intended to responsibly control nutrient contributions from pasture to stream. They are based on current science. No evidence has been presented by Plaintiffs' consultants that said guidelines and regulations are not being followed in the IRW. No scientifically valid evidence has been presented by Plaintiffs' consultants that concentrations of P in stream waters in the IRW increase as a consequence of surface runoff from pasture lands. Plaintiffs' consultants **assume** that P will be transported from properly managed, litter- amended pasture lands to streams, but provide no documentation that such transport actually occurs.

Given the importance of water flow path in determining the potential movement of P and fecal indicator bacteria from pasture to stream, and the regulations and guidelines that now govern the application of poultry litter on pasture lands in the IRW, it is unlikely that land application of poultry litter is an important source of these constituents to streams in the watershed. Federal and state guidelines and regulations are intended to limit the potential for pollutant transport, and Plaintiffs' consultants have provided no information that would suggest that such guidelines and regulations are ineffective in that regard. Furthermore, Plaintiffs' consultants have not demonstrated that poultry litter application is responsible for observed concentrations of these constituents in non-urban streams. Rather, they ignore the likely importance of cattle, erosion, septic systems, other livestock, wildlife, and other well known potential sources of these constituents in non-urban areas.

Plaintiffs' consultants did not demonstrate that land application of poultry litter plays an important role in contributing P or fecal indicator bacteria to streams in the IRW. Furthermore, to the best of my knowledge Plaintiffs' consultants did not present a clear indication that land application of poultry litter causes or contributes to high concentrations of P or fecal indicator bacteria in streams **anywhere** under the same general environmental conditions and the same guidelines and regulations as are now applicable in the IRW**.**

Most of the published literature that documents movement of P from pasture land subsequent to poultry litter land application was either based on experimental studies that involved small plots or treatment boxes, and/or relied on irrigation with artificial rainfall at rates that exceed typically observed rainfall intensities recorded in the IRW (Table 11-1**)**. Some studies have been conducted on clay soils (which promote overland flow) or may have included the potential influences of both livestock grazing and land application of poultry litter, with no ability to discriminate between these two potential sources.

12. *Plaintiffs' consultants have not identified a unique signature that indicates the presence of water contamination from poultry litter application, or any other potential source of P or fecal indicator bacteria to stream water in the IRW. Plaintiffs' consultant, Dr. Olsen, incorrectly claimed on page 2 of his May 14, 2008 report for this case that his PCA analyses:*

> ***identified two major sources of contamination in the IRW: poultry waste disposal and WWTP discharges.***

He went on to state:

> ***Poultry waste is by far the dominant contamination source in the IRW when compared to other sources….chemical contamination from cattle waste is not dominant in the basin and only represents a minor source. In the PCA, the chemical and bacterial composition of poultry waste creates a distinct chemical signature that contains both phosphorus and bacteria.***

There are numerous problems associated with Dr. Olsen's interpretation of his PCA analyses. These problems are discussed at length in several of the expert reports prepared for the Defendants in this case. Some of the most important, in my view, are the following:

1) Dr. Olsen did not collect and analyze samples to reflect the presence of the many known and suspected sources of NPS pollution of stream water that are found in the IRW, including septic systems, runoff from roads and other erosion sources, urban storm runoff, swine manure, biosolids, and commercial fertilizer application. He collected only a few samples for his PCA to characterize the composition of runoff from cattle pasture areas. If Dr. Olsen's PCA was intended to indicate contaminant sources, as he claims, at a minimum he should have adequately sampled all of the

potential sources expected to be important. Rather, Dr. Olsen's sampling of potential source areas was focused almost entirely on his edge-of-field samples, which he **presumed** were affected by poultry litter, and (in most cases) only poultry litter. As reported by Dr. Glenn Johnson (November, 2008), Dr. Olsen collected samples to characterize the signature of potential sources for his SW3 PCA run (his primary run that was focused on surface waters). But 64 of those were edge-of-field samples, and only 6 were collected with the intent of examining the signature of other sources: 4 to characterize WWTP effluent and 2 to characterize cattle pastures to which poultry litter had never been applied. It appears that Dr. Olsen **assumed** that land application of poultry litter was the only important source of NPS water pollution in the IRW, and that it was therefore not necessary to sample other sources with any degree of rigor, or (in most cases) at all. Since Dr. Olsen assumed prior to conducting his analysis that poultry litter was the dominant source, it is not surprising that he would conclude as a result of his analyses that poultry litter was the dominant source.

2) Interpretation of his principal components as indicative of source types is unfounded. Dr. Olsen interprets his principal component 1 as indicative of influence by poultry litter on water quality. This is a subjective judgment. His PC1 axis could represent anything, or it could represent nothing. In order to accept that PC1 reflects poultry influence, we must accept Dr. Olsen's judgment on that. The PCA method does not tell us what PC1 represents; Dr. Olsen tells us what he believes it to represent. Dr. Olsen does not offer sufficient documentation to demonstrate that his interpretation is correct. Furthermore, Dr. Olsen assumes that his PC1 and PC2 axes can discriminate among sources. In fact, these derived factors can reflect many different things; they could reflect different sources, or differences in contaminant behavior in the environment, or (as discussed by Dr. Glenn Johnson's rebuttal report; Johnson 2008) the propensity for individual constituents to travel through the watershed in dissolved versus particulate forms, some combination of the above, or some other factor(s) that reflect differences and similarities among data points. The PCA really only indicates the extent of similarity among data points. It does not tell the user how or why the data points are more or less similar or different. That must be decided by the user, and that decision is subjective. Dr. Olsen provides no scientifically defensible evidence that his PC1 and PC2 axes reflect sources, poultry litter or otherwise. He defends his interpretation on the basis of spatial analysis of samples from only a few locations. This is described by Dr. Glenn Johnson (2008), who conducted a much more extensive examination of the spatial patterns in Dr. Olsen's PC scores. Dr. Glenn Johnson (2008) reported a large number of inconsistencies in Dr. Olsen's interpretation. In fact, many sample points that showed PC1 scores greater than his 1.3 cutoff (supposedly reflecting poultry dominated water quality) were located in areas of low poultry house density (Johnson's Figure 2-5). Many sample points that showed PC1 scores that were greater than 1.3 were located in areas that were immediately downstream from urban development (Johnson's Figure 3-1). Thus, the spatial patterns in Dr. Olsen's data do not support his contention that his principal components reflect different pollutant source types. It is clear that PC1 does not represent poultry influence (Glenn Johnson 2008). It is therefore unclear what value his PCA provides to the Plaintiffs' case.

3) Dr. Olsen claims that the ratios and concentrations of various constituents in various portions of the watershed reveal where those constituents came from. This ignores the likelihood that different chemical and biological components move through the environment to varying degrees and are diluted to varying degrees (Connolly 2009). He simply **assumes** that similarities in the chemical and biological constituents in presumed source types or source areas are conserved as those constituents move down through the watershed from poultry barns to fields, to soil, to streams, to Lake Tenkiller. Yet Dr. Olsen provides no evidence to support that assumption.

4) The scores plot for Dr. Olsen's primary PCA run (termed SW3), presented as Figure 6.11-18a by Dr. Olsen and again as Figure 2-1 by Dr. Glenn Johnson, clearly shows that Dr. Olsen did not obtain good clustering of data points along his PC1 and PC2 axes, which are the only axes that he judged to be important to his allegations. His selection of PC1 equal to 1.3 as the benchmark for identifying samples impacted by poultry litter is completely arbitrary, and he does not adequately defend this arbitrary selection that is so central to his PCA interpretation. Dr. Olsen makes the subjective determination that his quantification of PC1 in a water sample higher than 1.3 indicates that poultry litter is the dominant influence on the chemistry and biology of that water sample. He offers absolutely no basis for that judgment. Incredibly, his plot of PC1 versus PC2, on which he makes that judgment, illustrates that he draws his subjective line (at PC1 equal to 1.3), right in the middle of the densest concentration of data points on his graph (his Figure 6.11-18e). His PC1 versus PC2 plot does not reveal any objective basis for determining at what PC1 score he should set his arbitrary boundary between poultry dominant influence and not poultry dominant influence. Again, we are asked to accept Dr. Olsen's interpretation of where that arbitrary boundary should lie.

5) Even Dr. Olsen recognized the subjective nature of his benchmark of PC1=1.3 as a determinant of poultry impacted surface water. He arbitrarily changed his interpretation of six stream samples collected near Tahlequah from "poultry impacted" to "not poultry impacted", even though his PC1 score was greater than 1.3 for each of those samples; Dr. Olsen did not reveal in his report that he had changed these data points. He stated in his deposition that he made this change because:

   > ***I decided that those were not impacted by poultry, and I colored them green…***

   This subjective change in interpretation by Dr. Olsen is discussed in detail by Dr. Glenn Johnson (2008, See Dr. Johnson's Figures 3-1 and 3-2). There is no place in objective science for Dr. Olsen's decision to arbitrarily change the color (source interpretation) of those six sample locations, especially without acknowledging that subjective action in his report. Dr. Olsen also collected three samples of WWTP effluent from the treatment plants in Springdale, Rogers, and Siloam Springs, along with one sample of stream water just downstream from the Lincoln WWTP. Dr Johnson (2008, page 37) indicated that all of those samples had PC1 scores in Dr. Olsen's SW3 PCA run that were greater than 1.3, and Dr. Olsen therefore classified them as poultry impacted. In deposition, Dr. Olsen acknowledged that these samples should not have been classified as poultry impacted, even though they had PC1 higher than his arbitrary 1.3 cutoff value, and that they needed to be removed from his poultry-impacted calculations. Thus, Dr. Olsen apparently feels that he should have arbitrarily changed the color of those dots on his map as well. The PC1=1.3 criterion only seems to apply as a benchmark for indicating that water is poultry impacted in situations where Dr. Olsen agrees that the sample might be poultry impacted. This is not a unique signature of impact of a particular source; it is a subjective determination made by one person (Dr. Olsen) as to what is the cause of impact.

6) A high percentage of the samples used by Dr. Olsen in his PCA had missing values, especially for fecal indicator bacteria (among the most important parameters in this case). For the missing values, Dr. Olsen substituted the mean of all of his samples, regardless of whether they came from edge-of-field or stream, regardless of whether that stream was located in a forest or a pasture or below a WWTP. This would result in the potential for serious bias in the samples that had substituted data. Dr. Olsen did not investigate or attempt to correct for such bias. Furthermore, Dr. Cowan (2008,) concluded that :

> ***Dr. Olsen has plugged in so many missing values that a very significant part of the dataset is made up by Dr. Olsen.***

Dr. Cowan (2008, his Chart 6) also showed that observations that were missing some data were unlike those that were not missing data, suggesting that Dr Olsen's made-up data may have biased these sample points.

These, and many other, problems associated with the conceptualization, implementation, and interpretation of Dr. Olsen's PCA are discussed in greater detail in the rebuttal reports of Dr. Glenn Johnson (2008), Dr. Steven Larson (2008), and Dr. Charles Cowan (2008). Taken together, these problems indicate that Dr. Olsen's conclusion that his PCA identifies the principal sources of P and fecal indicator bacteria in the IRW is without merit.

13. There are many known sources of NPS pollutants in the IRW. Plaintiffs' consultants provide no convincing evidence that poultry litter application is significant, compared to other known sources.

In Sections III.5 and III.6 of this report, I discuss some of the major sources of P and fecal indicator bacteria to streams in urban and agricultural areas, respectively. The most important in the IRW are probably WWTP effluent, urban runoff, cattle, septic systems, erosion, Lake Frances, other livestock, and wildlife. Because many of these potential sources of point and nonpoint source contribution to streams are at least partly restricted to urban and/or agricultural land use, nutrient (P and N) concentrations in some areas in the United States have been shown to increase with percent agriculture and decrease with percent forest (Riseng et al. 2004). This is a well known pattern. It is to be expected that concentrations of P and fecal indicator bacteria within the IRW would be higher in areas influenced by urbanization, agriculture, and other human activities, as compared with forested areas. One cannot determine, based solely on that pattern, the relative importance of the different potential sources of these constituents within the urban and agricultural land use types. Plaintiffs' consultants did not conduct additional analyses to try to determine the relative importance of these various potential pollution source types. Rather, they generally ignored or dismissed them as unimportant.

Contamination of surface waters in the IRW with P and/or fecal bacteria is an extremely complex issue. There are many sources of both constituents and they are widely distributed. They are not confined to a single land use or practice. There is no one-size-fits-all explanation for the occurrence of concentrations of total P and fecal bacteria indicators above existing water quality standards in some streams within the IRW. It is likely that a high percentage of the people and the animals that live in the watershed share to some degree in contributing these constituents to surface waters. I have seen no data that would suggest to me that the spreading of poultry litter is an important cause of P or fecal bacteria indicator concentrations above water quality standards in the IRW. Where concentrations of either or both of these parameters are above water quality standards in non-urban areas, there are multiple land use activities, and multiple potential sources of P and fecal indicator bacterial contribution. Nevertheless, the most striking spatial pattern appears to be the proximity of the sites with highest P and, to a lesser extent, fecal indicator bacteria values to the location of waste water treatment plant effluent and urban development.

Dillon and Kirchner (1975) reported the following typical values for P export from comparable sedimentary watersheds:

Forest – 11.7 mg/m^2/yr

Forest and pasture – 23.3 mg/m^2/yr

Intensive agriculture – 46 mg/m^2/yr

Urban – 110 to 1,660 mg/m^2/yr

Thus, based on these data summarized by Dillon and Kirchner (1975), the export of P from urban areas is many times higher per unit land area than is the export of P from forest and pasture land.

14. *When selecting "Reference" streams, Plaintiffs' consultants incorrectly chose watersheds that are generally free of human influence, rather than those that have similar human impacts but lack appreciable poultry operations.*

Plaintiffs' consultants compared chemical and biological conditions in the IRW to hand selected "Reference" reservoirs and streams that were selected to represent relatively pristine conditions. Such watersheds are not appropriate points of reference for evaluating the influence of land application of poultry litter on water quality. Rather, appropriate reference watersheds for the scientific questions at hand in this case would be those that have similar mixes of land use to the IRW (urban, rural residential, forest, pasture lands) with similar densities of people, cows, and other animals, but few or no poultry operations. A comparison of the IRW with more appropriate reference watershed conditions for this case yields very different conclusions than those presented by Plaintiffs' consultants. My analyses show that watersheds having generally similar distributions of land use, but limited poultry operations, exhibit stream concentrations of P and fecal indicator bacteria that are generally similar to those in the IRW.

Dr. Olsen describes in his report (Olsen 2008), collection of what he terms reference waters. On page 2-23 of his report, he states that he:

> ***selected reference locations in representative watersheds that were similar to the IRW, but were not affected by poultry operations.***

This is not, in fact, what he selected. The reference watersheds selected by the Plaintiffs' consultants were *not* similar to the IRW. Rather, they were selected to represent relatively pristine conditions with minimal human perturbations. On page 2-47 of his report, Dr. Olsen describes his use of reference waters as follows:

> ***The use of a reference waterbody that is minimally impacted and is within a similar ecosystem is important to the interpretation of the biological and chemical data. Typically, a reference waterbody provides the basis for making comparisons and evaluating impairment or injury; however, in some areas it may be difficult to find an appropriate reference area that has not been impacted by agricultural operations or other human-induced activities.***

Dr. Olsen further stated on page 2-49 that:

> ***The selection of reference streams were additionally based upon the results of sediment chemistry (typically total phosphorus <250 mg/kg), water quality (total phosphorus <0.030 mg/L…..***

Thus, as Dr. Olsen describes, he selected as reference streams those that he could find that were minimally influenced by human activities and which contained low concentrations of phosphorus in the water and in the sediment. Based on analyses of data collected from these streams that he selected specifically to be low in P concentration, he concludes that P is low in reference streams. Obviously, this should come as no surprise!

Dr. Stevenson (2008, page 4) defined reference conditions as

> ***the physical, chemical, and biological condition found in streams having watersheds with the lowest level of human activities.***

Using the criteria adopted by Plaintiffs' consultants as the definition of reference conditions, they apparently sought to find and designate as "Reference" stream watersheds those that they could find that were as free of human activities as possible in order to attempt to reflect background conditions.

Dr. Stevenson confirmed this in his deposition on January 8, 2009 (deposition transcript, page 56). In discussing the Plaintiffs' reference stream sites, the following exchange took place:

> ***Q. And what was the selection process for those two sites, do you know?***
>
> ***A. …in the conversations about why those were selected and why they were appropriate, it was largely because there was very little human alteration of the watershed currently upstream from the sampling locations.***

A stream that has low P and minimal influence of human activities within the watershed is **not** an appropriate reference stream for the scientific questions at hand in this case. Among the objectives of this evaluation is not an attempt to compare the water quality of a pristine stream relatively unaffected by humans to streams in the IRW. Such an objective may be appropriate for other purposes, but not if one is attempting to determine the influence on water quality of one particular land use activity, as Plaintiffs' consultants set out to do in this case. In this case, Plaintiffs' consultants have chosen to focus on land application of poultry litter, nearly to the exclusion of every other potential source of the constituents of interest. (See additional discussion of this in Section III.20.) For that reason, an appropriate point of comparison for streams in the IRW would be a stream that is generally similar in most respects, including land use (mix of urban, rural residential, and agricultural lands), but that differs in that it does not have a well-developed poultry industry. An appropriate comparative stream cannot be selected based on its water quality; rather, it must be selected based on its land use. We want to know what the water quality would be (not pre-select it) if the watershed was similar in most respects, but did not have poultry. Plaintiffs' focus on reference watersheds generally lacking human influence is totally inappropriate.

Plaintiffs' consultant Dr. Olsen identified three stream watersheds and two reservoirs as reference watersheds. I address here Dr. Olsen's selection of reference stream watersheds. Defendants' expert, Dr. Connolly (2008), addresses Dr. Olsen's selection of reference reservoirs.

I attempted to locate several comparative stream watersheds in the general vicinity of the IRW using more appropriate criteria. My focus was on location of stream watersheds that 1) had generally similar mixes of land uses, including the presence of urban areas and grazing lands, but that were not located in areas that have high density of poultry operations; 2) were reasonably close to the IRW location and generally in the same size range as the IRW; and 3) had good availability of water quality data. Poultry houses were then counted by examination of aerial photographs.

Aerial photography interpretation was conducted for the comparative watersheds of Verdigris, Caney, Hugo (including its subwatershed, Sardis, that was analyzed by Connolly, 2008), and James, and for Plaintiffs' Reference watersheds RS010005, RS010014, and REF2 to identify poultry houses. Aerial photographs at 1- and 2-m resolution were acquired from the USDA National Agriculture Imagery Program (NAIP). Sources of the aerial photographs included the following:

USDA Geospatial Data Gateway http://datagateway.nrcs.usda.gov/

- Oklahoma – 2008 Imagery: 1-m
- Arkansas – 2006 Imagery: 2-m
- Missouri – 2007 Imagery: 1-m

Kansas Geospatial Community Commons http://www.kansasgis.org/catalog/catalog.cfm

- Kansas – 2006 Imagery: 1-m

In ArcMap, the digital aerial imagery was overlayed with watershed boundaries and methodically reviewed, quad by quad, to identify structures which met or exceeded a minimum size criterion of 100 ft in length by 20 ft in width. Once identified, each point was added to georeference the house location, and a graphic screenshot of the structure, point, and reference scale bar was created. These graphic screenshots were submitted to Dr. Billy Clay for final review. Dr. Clay examined these houses and made the final determination of poultry house locations, which were tabulated by E&S staff.

Results indicate that there is not an ideal comparative watershed available. Nevertheless, several comparative watersheds were identified that are much more appropriate for comparison with the IRW for this case than are the reference watersheds selected by Plaintiffs' consultants.

Figure 14-1 shows the locations of the IRW (along with its major subwatersheds; outlined in red), the three reference stream watersheds selected by Plaintiffs' consultants (outlined in orange), and three candidate comparative watersheds that we selected (outlined in black). Also shown on Figure 14-1 is the poultry house density across the landscape from the agricultural census data. As shown on the map, the three candidate comparative watersheds are all located in areas of low poultry house density in Oklahoma and surrounding states (Missouri and Kansas). Figure 14-2 shows the same watersheds, along with the land use coverages. Each of the candidate comparative watersheds has some urban land use, along with a mixture of pasture land and forest. Selected watershed characteristics are given in Table 14-1.

Figure 14-3 shows the total P concentrations for each of the major subwatersheds in the IRW, along with Plaintiffs' reference watersheds and our candidate comparative watersheds. The graph depicts the median, quartiles, and geomean of available measurements for each watershed (represented at the downstream sampling station on each).

For the subwatersheds of the IRW, two sets of data are shown: data collected by USGS and data collected by OWRB. The reason that the IRW data are split out according to data source is explained more fully below. In essence, because USGS changed their sampling protocols in 1999 to focus on sampling during high flow periods, there is a bias in the USGS data for the purposes of comparing them with data from other sources. The bias towards high flow in the USGS data is illustrated in Figure 14-4. Higher percentages of the available samples were collected under high flow conditions by USGS in the IRW, as compared with samples collected by the OWRB in the IRW, and as compared with available data for the comparative watersheds . The pattern of bias in the USGS data collected within the IRW towards high flow sampling conditions is clear, using as the flow criterion either the 70th percentile or the 90th percentile of long-term flow data. Because of this bias towards high flow, and given the strong association between flow and water quality (especially for fecal indicator bacteria) described in Section III.10, the USGS data are less useful in an evaluation of differences and similarities in water quality between streams in the IRW and the comparative river watersheds.

Concentrations of total P at the lowest sampling station in each of the major subwatersheds of the IRW are generally higher than in Plaintiffs' reference watersheds (Figure 14-3). This is to be expected because one of the criteria used by Plaintiffs' consultants in selecting their reference watersheds was that the stream in each reference watershed had low P concentrations. Since the reference watersheds were selected to have relatively low P concentrations, it comes as no surprise that they do indeed have relatively low P concentrations. In contrast, the comparative watersheds that we selected (the selection was made irrespective of stream P concentrations) to have generally similar land uses, except without much poultry farming, have total P concentrations that are similar to, or higher than, concentrations observed in the IRW streams that have substantial poultry farming. Thus, there is no indication in these data to suggest that the presence of poultry farming in the IRW has caused the concentrations of total P in stream water to increase relative to comparative streams that have generally similar land use, but little poultry farming. None of the comparative watersheds available for making this comparison are perfectly matched to streams in the IRW. Nevertheless, the comparative watersheds that we selected are clearly more appropriate as reference conditions, if one is interested in evaluation of water quality in watersheds that are generally similar in land use to the IRW (minus poultry), than are the reference watersheds selected by Plaintiffs' consultants specifically to be low in P concentrations (one of which [RS010014] actually had relatively high poultry house density [Table 14-1]). Total P concentrations in streams within the comparative watersheds that we selected were not lower than total P concentrations in streams in the IRW. Based on this comparison, there is no evidence that streams in the IRW contain higher total P concentrations as a consequence of poultry farming in the IRW.

15. *Despite claims by Plaintiffs' consultants to the contrary, water quality in the IRW has* ***not*** *been deteriorating in recent years.*

Plaintiffs' consultants did not collect stream or lake water quality data in the IRW over a long enough period of time to determine whether conditions were in fact changing over time. Nevertheless, they made statements in the Preliminary Injunction hearing suggesting that water quality conditions were deteriorating over time in response to actions of the Defendants. Plaintiffs' consultants have presented no valid data to support such a claim. They did present an incorrect and invalid analysis in the Preliminary Injunction hearing based on USGS data. However, the pattern in the data that Plaintiffs' showed in the Preliminary Injunction hearing was determined by a change in USGS sampling procedures described in Section III.10 of this report.

The Comprehensive Basin Management Plan for the Oklahoma portion of the IRW (Haraughty 1999, page 28) evaluated changes in water quality in the IRW between 1981-82 and 1991-92. They concluded that water quality was "essentially similar" between these two time periods. More recently, Haggard and Soerens (2006) claimed that P concentrations in the Illinois River drainage area in northwestern Arkansas have been decreasing, not increasing, over time. They attributed this decrease primarily to reduced effluent P concentrations from municipal discharges in the headwaters, citing Ekka et al. (2006) in support of that contention. Connolly (2008) reported that, during base flow conditions (which occur about 80% of the time at this sampling site, Dr. Connolly, pers. comm., 2009), the concentration of total P in the Illinois River at Tahlequah decreased by about 40% from the period 1997-2003 to the period 2004-2008. Connolly (2008) attributed this recent decline in base flow total P concentration to decreased contributions of P from WWTPs in the watershed.

Data are available from several databases, including data produced by Plaintiffs' consultants for this case and also the Oklahoma Water Resources Board and the U.S. Geological Survey, with which to evaluate the extent to which stream water quality in the IRW has been improving, deteriorating, or remaining stable over time. Total P and *E. coli* data collected at Tahlequah, at the lower end of the Illinois River just above Lake Tenkiller, are shown in Figure 15-1 for the period 1998 to 2008. For *E. coli*, there is no consistent trend in either database. There are too few samples, and/or too much temporal variability in the *E. coli* data, to fully evaluate whether or not concentrations are changing over time at that site. For total P, however, both databases suggest that the concentration of total P has been decreasing over the past decade. The decrease is highly significant ($p<0.001$) for the OWRB data, in agreement with the findings of Connolly (2008) for base flow conditions. There is substantially more variability in the USGS database, but this variability is restricted mainly to the samples collected under high flow conditions (defined as flows above the 70th percentile of flow at the site).

The patterns of response in the USGS data require additional explanation, which is provided below. In 1999, the USGS changed their protocols for stream sampling in the IRW to focus on sample collection during periods of high discharge (stream flow). Because a number of water quality parameters, including fecal indicator bacteria and P, are very responsive to changes in discharge, this change in USGS sampling protocols can have important impacts on interpretation of stream monitoring data collected in the IRW. Specifically, the concentrations of these parameters tend to be higher during high flow conditions, as compared with low flow conditions. See further discussion of this issue in Section III.10.

The bias in the available USGS water quality data collected within the IRW towards high flow conditions can be seen by comparing USGS data collected inside the IRW with USGS data collected outside the IRW. Water quality data collected by USGS for fecal indicator bacteria (*E. coli* or FCB) and total P are available at 6 gaged USGS sites inside the IRW and 16 gaged sites outside the IRW within Oklahoma. Nearly one-fourth (24%) of the stream samples collected by USGS inside the IRW were collected under flow regimes that exceeded the 90th percentile of flow at that site (Figure 15-2). In other words, 24% of the stream samples collected by USGS inside the IRW and measured for total P were collected under the top 10% of flow conditions. In contrast, stream sites sampled by USGS outside the IRW had flow above the 90th percentile (top 10% of flow conditions) on only 13% of the sampling occasions. The difference between flow conditions for sites sampled by USGS inside versus outside the IRW were even more pronounced for the highest flow conditions (95th percentile and 99th percentile of long-term flows at each site). At the 95th percentile of flow, a sample was twice as likely to have been collected (16 % versus 8% of samples) inside the IRW; at the 99th flow percentile, a sample was three times as likely to have been collected inside versus outside the IRW (9% versus 3%). Thus, the stream data for total P collected by USGS inside the IRW are strongly biased towards high flow conditions. This is not a criticism of the USGS sampling program. They specifically targeted high flow conditions, and were very successful in sampling under such conditions. This bias must be considered when interpreting the resulting USGS data for the IRW.

The bias in the USGS data towards high flow within the IRW is even more pronounced for fecal indicator bacteria than it is for total P. USGS was more than 7 times as likely to sample for fecal indicator bacteria inside versus outside the IRW at flows above the 90th flow percentile (36% versus 5%) and at flows above the 95th flow percentile (22% versus 3%); and USGS was 11 times more likely to sample for fecal indicator bacteria inside versus outside the IRW at flows above the 99th flow percentile (11% versus 1%). Thus, if sampling was conducted independent of flow, one would expect that *E. coli* samples would be collected at flows above the 99th percentile only 1% of the time; this is what happened outside the IRW. In contrast, such extremely high flows were represented by 11% of the USGS samples collected inside the IRW and analyzed for *E. coli*. These differences in flow conditions at the time of sample collection bias the USGS data and make it difficult to use those data to evaluate general water quality conditions in the IRW for flow-dependent constituents such as P and fecal indicator bacteria. These differences also complicate any attempt to use USGS data in the IRW to examine potential changes in water quality over time. This may help to explain why there is a very clear and obvious improvement (reduction) in total P in the Illinois River at Tahlequah (Figure 15-1) using OWRB data, but not using USGS data.

Data reported by other investigators have also suggested an improvement, rather than a deterioration, in stream water quality in recent years. For example, Tortorelli and Pickup (2006) reported stream chemistry data at three USGS gaging stations on the Illinois River, Baron Fork, and Flint Creek. In general, the mean and median total P concentrations decreased in runoff (non-base flow) samples over the period 2000 through 2004. At all sampling sites considered by Tortorelli and Pickup (2006), both the mean and median TP concentrations averaged over the period 2002 though 2004 were lower than the concentrations averaged over the period 2000 through 2002. Haggard and Soerens (2006, page 281), citing the Ekka et al. (2006) study of the effects of municipal effluents on streams in the IRW, also acknowledged that P concentrations in the IRW have been decreasing over time; they credited reductions in municipal discharges for at least part of the decrease in stream P concentration.

Plaintiffs' consultants collected lake water data from Lake Tenkiller that allow an evaluation of the extent to which water quality has changed over time, although there may not be enough years of data to conclude that there have been statistically significant changes in recent years. The concentrations of total P at the lacustrine (lake-like) sampling stations, LK-01 and LK-02 in Lake Tenkiller appear to have decreased in recent years, based on data summarized by Cooke and Welch (2008, their Figure 7). I have extracted the data from Cooke and Welch's Figure 7 for the lacustrine lake sampling site closest to the dam (site LK-01) and show their measured total P values at that site (six years of data represented). Total P concentrations in the more recent years (2005-2007) were about half the values measured in the earlier years (1974, 1992, 1993; Figure 15-3). I also show in Figure 15-3 the median and quartile values of total P measured at sampling sites near the dam in each of 135 reservoirs in Missouri, reported by Jones et al. (2004). The comparable total P values measured in Lake Tenkiller during the three most recent sampling years (Cooke and Welch 2008) are lower by about a factor of two than the 25th percentile of the distribution of the Missouri reservoir data. In other words, more than 75% of the Missouri reservoirs studied by Jones et al. (2004) had total P concentrations that were much higher than Lake Tenkiller.

The more recent years for which total P data were reported for Lake Tenkiller site LK-01 by Cooke and Welch (2008) were drier than the earlier years for which they reported data, as represented by total stream discharge at the two principal downstream USGS gaging stations on the Illinois River and Baron Fork (Figure 15-4). This could cause lower concentrations of total P in lakewater because more P is generally transported to the lake under high flow conditions, which are more common during wet years, as compared with lower flow conditions, which are more common during drier years. Clearly, 1974 was a wet year, and river discharge was high. The years 1992 and 1993 were also characterized by higher river flows than the long-term median values, whereas 2006 was a drought year (both on an annual and a summer basis); 2005 was dry during summer but near the median value on an annual basis. The year 2007 was fairly typical of the long-term record. However, there were large differences in river discharge within the three most recent years sampled and reported by Cooke and Welch (2008) on both an annual and a summer basis. Total summer flow in 2007 was more than double that of either 2005 or 2006; total annual flow in 2005 was more than three times higher than in 2006, and total annual flow in 2007 was more than twice as high as 2006. Despite these large differences in flow within those three years, the concentrations of total P in the lacustrine portions of Lake Tenkiller reported by Cooke and Welch were remarkably similar in 2005, 2006, and 2007. In addition, the differences in annual flow between 2005 and 2006 were more than twice as large as the differences between 2005 and 1992. A similar pattern is seen for summer values: the difference in flow between 2007 and 2006 is larger than the difference between 1993 and 2007. It is therefore unlikely that the large decrease in total P observed between the sample occasions in the early 1990s compared with 15 years later can be attributed to differences in river flow. If that was the case, we should also see large differences in total P concentration within the more recent three year period (2005-2007); we do not. Thus, it is unlikely that the observed decrease in total P between the 1990s and the period 2005-2007 is attributable to the drier conditions observed during the more recent years of data collection.

It is therefore curious that Cooke and Welch (2008, page 33) stated:

> ***…P concentrations and chl are high and increasing…***

Examination of their own data shows that TP concentrations appear to have decreased at lacustrine sites in Lake Tenkiller; there is certainly no evidence that they are increasing. Defendants' expert, Dr. Horne (2008) presented data illustrating that chlorophyll *a* stayed about the same during recent decades. Thus, the claim by Cooke and Welch (2008) that P and chlorophyll *a* are increasing is inconsistent with the available data.

It is important to recognize that, in addressing the question "Are conditions getting better?", it is appropriate to focus on data collected in recent years. Comparison between data points estimated for the distant past and one or more recent years tells us nothing about changes that are occurring now. It should come as no surprise that water quality in the IRW today would not likely be as high as it was many decades ago, prior to the large increase that occurred in the populations of people and their animals in the watershed. However, there have been several efforts in recent years to improve conditions. These have included, but are not necessarily limited to, improved waste water treatment, ban on phosphate detergents, and perhaps others. As presented above, examination of a variety of data representing conditions in the stream and in the lake since about the late 1990s or early 2000s suggests that water quality in the IRW is improving in response to such actions. Plaintiffs' consultants claim that water quality is deteriorating, but they provide no basis to support those claims. Statements by Plaintiffs' consultants that water quality conditions in the IRW are getting worse over time are simply wrong.

16. *Analyses presented by Dr. Fisher are claimed to reflect an increase in the populations of poultry in the IRW that match P concentration data in the sedimentary record of Lake Tenkiller. Dr. Fisher further claims that the poultry population trends match the sediment P data better than do the population trends of humans, cattle, and swine. These claims are not accurate.*

During the September 4, 2008 deposition (page 341) of Plaintiffs' consultant, Dr. Fisher, he stated that Figure 33 in his report indicates that the change in total poultry population over time:

> **fits the general functional form of the change in phosphorus over time in the lake cores.**

A similar statement is made on page 61 of his May 15, 2008 report, where he also claimed that the sediment total P data fit this poultry population general functional form and slope better than the overall functional form and slope of the populations of beef cattle, dairy cattle, swine, or humans.

Dr. Fisher cited this as one of his lines of evidence pointing to poultry litter as the dominant source of P in the IRW. However, Dr. Fisher neglected to reveal that the change in the human population (and to a lesser extent also the change in the cattle population) over the same time period also fits the general functional form of the change in phosphorus over time in the lake cores. The data in Dr. Fisher's Figure 33 were plotted in such a way as to conceal the relationship between sediment P and changes in the populations of humans and cattle. First of all, Dr. Fisher has converted poultry, humans, and cattle into animal units (units of 1,000 lbs of animal). This is misleading because it requires unsubstantiated assumptions regarding the average weight of humans, cattle, and different forms of poultry, all of which have changed over time. It is further confused by the fact that most poultry within the watershed are only alive for a very small portion of one year, whereas humans and other livestock are much longer lived, typically being alive in the watershed throughout the entire year. Also, it is not appropriate to plot humans as animal units. Animal units are used for livestock management, largely to regulate grazing densities; the reason is because different species have different grazing needs and impacts, based partly on their weights. For example, cattle are substantially larger than sheep and several sheep will therefore have somewhat similar forage needs and grazing impacts as one cow. Humans are not grazing animals; they are not managed or sold in thousand pound increments. In addition, Dr. Fisher combines different types of poultry (broilers, layers, turkeys, etc.) into one poultry trend for his graphic, but splits cattle into two components (dairy and beef), again distorting the patterns that occur by increasing the poultry numbers but not the cattle numbers, whereas the issue is the same for both. But most importantly, by plotting the data on the scale used by Dr. Fisher, he obscures the relationships with variables other than poultry. Because there are many more of what he calculates as poultry animal units than there are what he refers to as human "animal units", one cannot ascertain from Dr. Fisher's graph to what extent the human population has increased during the time period over which sediment P concentrations may have increased.

Dr. Fisher states that the number of poultry animal units increased by a factor of 14.27 between 1954 and 2002, whereas beef cattle only increased by a factor of 5.44. Ignoring any problems associated with his designation of animal units, this is not an appropriate way to evaluate these data. He could have calculated the increase between some other early year and 2002, and come up with an entirely different result. For example, the data in his graph show that between 1960 and 2002 the number of animal units of poultry only increased by a factor of about 6.8, from about 250 on his graph to about 1700 on his graph. Is it reasonable to assume that there was such a large impact on P concentrations in the sediments of Lake Tenkiller during the six year period between 1954 and 1960 that his factor should change from less than 7 to more than 14 simply by changing the start year from 1954 to 1960? The selection of starting point is totally arbitrary, yet it has a large influence on the results of the calculation. To offer a more extreme example, we could choose a starting year that corresponds with the first year that poultry were introduced into the IRW. I don't know what year that was. But, for example, if there was only 1 animal unit of poultry (as reflected in his graph) in the watershed in 1900, then the increase from 1900 to 2002 would be a factor of 1,600, rather than a factor of 14. Dr. Fisher's Figure 33, and associated text on page 62 of his report are misleading. In fact, during the past half century, the numbers of poultry, people and cows have all increased greatly. There is nothing about Dr. Fisher's Figure 33 or associated text that is helpful in terms of trying to sort out the relative magnitudes of the various possible sources of NPS pollution (including poultry, people, and cows) within the IRW.

Plaintiffs' consultant Meagan Smith illustrated the extent to which graphing technique can distort trends in her considered materials with two graphs. One was constructed so as to reveal the patterns of increase in poultry, humans, cattle and swine over time, by plotting the population of poultry in millions and the other populations in thousands. The other graph was constructed to conceal the patterns in all species except poultry by plotting all of the populations in millions. I show Ms. Smith's two panel figure here as Figure 16-1**.** Ms. Smith's figure illustrates two ways of graphing her population data. On the top panel, she maps poultry numbers in units of millions, and she maps other populations (humans, cattle, and swine) in units of tens of thousands. On this top graph it is clear that substantial changes have occurred over time in the populations of all of these species. On the bottom panel, she maps all species in units of millions. Because there are fewer than a million individuals for three of the species considered (humans, cattle, and swine), it is impossible to discern from this bottom graph whether those populations have changed or not. One graph reveals changes that have occurred; the other conceals them. In her May, 2008 mass balance study (Smith 2008), her Figure 2 was constructed in the same fashion (although the numbers and time periods were slightly different) as the bottom panel of Figure 16-1**;** thus, trends over time are concealed in Figure 2 of the report that she submitted for this case. Dr. Engel's Figure 33 was also constructed in such a way as to largely conceal the changes that have occurred in the populations of all species considered except poultry.

In Ms. Smith's Figure 2, because there are so many more chickens than people in the watershed and because she chose to construct the graph using units of millions, the graph incorrectly (and misleadingly) conveys the message that only poultry populations have increased over time. Had she chosen to also graph mosquito populations, and used a graphing unit of trillions of individuals, perhaps she could have conveyed the message that only mosquito populations have changed, and that the change in the populations of humans, cattle, and poultry were all inconsequential compared to mosquitoes. This would be a distortion of the data. Clearly, one can select graphing units in such a way as to distort or hide changes in populations over time. This is exactly what Plaintiffs' consultants have done.

Dr. Fisher presented, in his report for the Preliminary Injunction hearing (Fisher 2008a), a graphic showing changes in populations over time of poultry and cattle, along with data on the concentrations of P in one sediment core (core 1) collected from Lake Tenkiller. In his May 15, 2008 report (Fisher 2008b), he presented a similar figure, based on all of Plaintiffs' sediment cores and including population trends for humans and swine. Dr. Fisher concluded from those analyses that the population trend for poultry explained his sediment P data better than the population trends for humans, cattle, or swine. In the analyses conducted for his May report, Dr. Fisher (2008b) chose graphing techniques that would conceal the increase in the populations of humans and cattle in the watershed during the last half of the 20th Century (See Figure 33 in Fisher 2008b).

In Figure 16-2, I show changes in the populations of humans and cattle over time in the IRW. I also show estimates from Defendants' expert Dr. Connolly of Lake Tenkiller sediment P concentrations, based on Dr. Connolly's correction of Dr. Fisher's sediment core dates. I do not attempt to distort the patterns by selecting graphing units that will mask the observed patterns. Rather, I show populations in units of thousands for humans and cattle, and units of millions for poultry. This figure shows that poultry, human and cattle populations in the IRW have all increased over time, and that the proportional changes in human and cattle population numbers have been similar to the changes that Dr. Fisher (with revised core dating estimates provide by Defendants' expert, Dr. Connolly, 2008) has estimated for P concentration in the sediments in Lake Tenkiller. On the basis of estimated population trends over time, in comparison with Lake Tenkiller lake sediment P data, one cannot determine what has been the cause of the changes in sediment P concentration. For one thing, this is merely a correlation, and correlation does not demonstrate causality. See detailed discussion of this issue in Section III.8. In addition, Dr. Fisher is not correct in his assertion that only the historical change in the poultry population has corresponded with changes in his estimates of P load to Lake Tenkiller sediments; as I have shown here, populations of cattle and humans have changed over the same time period. And finally, Dr. Fisher's argument here, once again, ignores the likelihood (or certainty) that there have been many contributors to P loads to Lake Tenkiller. His misguided effort to pin the responsibility on one source (land application of poultry litter) is without merit.

17. *Importing of P into the IRW in poultry feed does not demonstrate that the P imported into the watershed contributes P to streams. The P mass balance described by Meagan Smith and Dr. Engel reveals little about the relative importance of the various sources of P contribution to streams in the IRW. Importation of P into the watershed is only one component of the complicated set of processes that influence the potential transfer of P from pasture to stream.*

Meagan Smith performed mass balance calculations of P inputs and outputs to the IRW. Other Defendants' experts address errors or shortcomings in how this mass balance was calculated (c.f., Clay, 2008). Dr. Clay (2008) estimates that cattle produce more than twice as much wet manure in the IRW as do poultry. In addition, Dr. Clay estimates that cattle manure produced in the IRW contains more P than poultry manure produced in the IRW, and much of that material is deposited by cattle directly into streams or adjacent to streams where it can be easily transported to streams during rain storms. I therefore do not assume that Ms. Smith's calculations are correct or representative. Nevertheless, it is important to point out that this mass balance, even if it was done correctly, provides very little information about the likelihood of P transfer to stream water from poultry litter or any other source of P in the IRW. In the Executive Summary of her May 2008 report, Ms Smith indicates that:

> ***The purpose of the [*** mass balance ***] study was to determine the source(s) of phosphorus causing eutrophication of Tenkiller Ferry Reservoir and water quality degradation of the Illinois River and its tributaries.***

Despite her goals, a mass balance such as was performed by Ms. Smith for this case **cannot** identify P sources to stream or lake water. Nevertheless, many of the Plaintiffs' consultants cite this mass balance as one of the principal pieces of evidence in support of their contention that concentrations of P in stream water in the IRW can be attributed to land application of poultry litter. See, for example, Dr. Fisher's deposition testimony (September 4, 2008, pages 342 and 348).

There are three major problems with the ways in which Plaintiffs' consultants interpret the results of Ms. Smith's calculations. Each is described below.

First, and most importantly, Plaintiffs' consultants failed to acknowledge that the mere presence of P in the watershed does not demonstrate movement of P into streams. In order for P placed on the land to cause or contribute to P in a stream, in addition to being present within the watershed, the P must be placed in sufficient proximity to a stream and in addition there must be a transport mechanism to move that P from the land to the stream. Plaintiffs' consultants make no allowance for the importance of proximity to streams and/or pollutant transport mechanisms within the watershed. Based on the logic of Plaintiffs' consultants, I could import a million tons of P into the IRW and place it in a warehouse. On this basis, because I would represent the largest importer of P into the watershed, Plaintiffs' consultants would conclude that I was not only the largest importer of P from outside to inside of the watershed, but also that I was the major source of any P found in stream water throughout the watershed. Obviously, the P stored in my warehouse would not be contributing to adverse effects on stream water quality. The reasoning offered by Plaintiffs' consultants is faulty because it does not address issues of proximity of P-containing poultry litter to streams or the availability of transport mechanisms from the site of litter application to stream water. There is an entire field of science that attempts to address these complex issues. It is totally insufficient to merely quantify which potential sources bring the most P into the watershed; this quantification (even if it is done correctly) reveals little about the relative importance of the various potential sources of P to streams.

The second major problem with the way in which Plaintiffs' consultants use the results of this mass balance is that they dismiss the importance of cattle as contributors of P to streams on the basis of Ms. Smith's assumption that, because they graze on pasture grass with relatively little supplemental feeding, cattle:

> **"recycle the phosphorus already in the landscape."** (Smith 2008, page 3)

On this basis, Ms. Smith essentially ignores any possibility that cattle act as a source of P to streams. This is not consistent with the well-known fact that in many watersheds, including many in Oklahoma for which Total Maximum Daily Loads (TMDLs) have been calculated, cattle have been judged to represent the largest source of fecal indicator bacteria to streams. If cattle are the most important contributors of fecal indicator bacteria, it is likely that they may also be important contributors of P as well. Thus, it is not appropriate to simply dismiss their potential importance. A bacterial TMDL analysis for the ODEQ for the Upper Red River (Parsons 2008b, page 3-12) concluded that:

> ***Cattle appear to represent the largest source of fecal bacteria***

in this watershed. The same conclusion was drawn in bacterial TMDL analyses for ODEQ for the following additional watersheds:

- Boggy Creek area (Parsons 2007b, page 3-6)
- Sans Bois Creek area (Parsons 2008a, page 3-9)
- Little River area (Parsons 2007d, page 3-6)
- Washita River (Parsons 2007a, page 3-13)
- Canadian River (Parsons 2006b, page 3-8)
- Arkansas River sections and Haikey Creek segment (Indian Nations Council of Governments 2008, page 3-15)
- Neosho River (Parsons 2008c, page 3-14)
- Lower Red River (Parsons 2007c, page 3-10)
- Upper Red River (Parsons 2008b, page 3-12)

It seems odd that in all these TMDL analyses that have recently been conducted for ODEQ, it was concluded that cattle appear to be the most important source of fecal indicator bacteria in each watershed, yet Plaintiffs' consultants conclude that the 200,000 cattle in the IRW are unimportant in regard to transport of P to streams. The cattle feces that contribute fecal indicator bacteria are the same feces that contribute P to streams and to riparian areas adjacent to streams. In addition, cattle contribute to stream bank and riparian zone erosion, thereby further increasing their contribution of P to streams. It seems especially odd that Plaintiffs' consultants dismiss the importance of cattle with the weak argument that cattle merely recycle nutrients that are already present on the land surface.

Consider also that the Comprehensive Basin Management Plan for the Oklahoma portion of the IRW (Haraughty 1999, page vii) estimated that cattle (dairy plus beef) excrete more P within the watershed than do poultry (chickens plus turkeys). Dr. Clay (2008) reached the same conclusion. Haraughty (1999)) went on to state:

> ***This is important because beef cattle management is such that cattle often have direct access to streams. Thus, cattle may act as a point source and deposit the nutrients directly into the stream, while poultry waste accesses the stream mainly through overland flow. In addition, pasture management is not always optimal. Grazing land is scarce and pastures are often over grazed, resulting in poorer pasture with a lower capacity to process animal waste and prevent it from reaching the stream.***

Dr. Fisher acknowledged in his September 4, 2008 deposition (page 450-451) that Plaintiffs did not evaluate the extent to which cattle convert vegetative P into a soluble form present in cattle feces and transport it from the pasture to the water course or adjacent to the water course.

Third, Plaintiffs' consultants do not acknowledge the presence (based on Dr. Engel's GLEAMS model, as summarized by Dr. Bierman) within watershed soils of P in amounts that far exceed the quantities imported into the watershed in poultry feed. Dr. Bierman concluded that Plaintiffs' consultants' estimate of P transfer into the IRW for poultry (4,642 tons of P per year) represents less than 0.07% of the P present in soils within the watershed, as represented in Dr. Engel's GLEAMS modeling effort (Bierman 2009). Thus, if one assumes that Plaintiffs' consultants' estimate of P import into the watershed for the poultry industry is correct and that Dr. Engel's GLEAMS model estimate of the size of the soil P pool within the watershed is correct, P application to soils in the IRW each year through land application of poultry litter would change the amount of P in the watershed soils by less than one tenth of one percent, even if all of this P remained in the soil, with no export via runoff or animal harvesting.

As described above, Plaintiffs' mass balance, which is cited by several of Plaintiffs' consultants (including Dr. Engel) as an important part of their weight of evidence evaluation, only focuses on P sources; it totally ignores transport. EPA recognized the fallacy of this approach. In the text of their revised CAFO guidelines in 2003 (Page 7227), EPA stated with respect to manure or poultry litter land application:

> ***However, it is also possible that an operation might land apply in excess of agronomic rates but still not discharge, depending on such factors as annual rainfall, local topography, and distance to the nearest stream. The Panel recommended that EPA consider such factors as it develops requirements related to land application.***

Thus, EPA recognized that a P source, on its own, is not sufficient to cause increased concentrations of P in stream water. Availability of transport mechanisms must also be considered.

Plaintiffs' consultants used their mass balance calculations as the basis of their claims that:

> ***Poultry production within the Illinois River Watershed is currently responsible for more than 76% of P movement into the watershed (Engel, May 2008 Report, page 32)***

Other consultants for the Plaintiffs also drew conclusions or made assumptions on the basis of these mass balance calculations. For example, Dr. Stevenson stated in his January 8, 2009 deposition (transcript page 179) stated, when asked about sources of P in the IRW:

> ***Well, based on the information I have about the amount of phosphorus that comes in and the phosphorus concentrations that were in the stream, my reasonable conclusion is that poultry houses and the spreading of the manure on the lands around the streams is the source of that phosphorus in the stream.***

Such claims are misleading. Plaintiffs' mass balance tells us little about the extent to which land application of poultry litter may or may not add P to streams in the IRW. It certainly does not provide the basis for such a quantitative estimate. The extent to which any one industry is responsible for movement of P, or any constituent, into the watershed on its own is not an important determinant of the causes of water pollution of streams within that watershed.

18. Plaintiffs' consultants' water quality sampling program lacked appropriate quality assurance.

A number of breaches of standard sampling procedures by the Plaintiffs' field sampling personnel were recorded by Conestoga-Rovers and Associates (CRA), who observed, photographed, and shot video footage of some of the state's sampling effort in 2006 and 2007. In my opinion, these procedural breaches that were summarized by CRA were sufficiently serious as to cast doubt on the ability of Plaintiffs' consultants to defend the validity of their field data. Some of the analyses conducted by Plaintiffs' consultants for this case relied on only a small number of data points to form the basis for their conclusions. This was particularly the case for some of Dr. Olsen's analyses of potential sources of constituents to stream water in his PCA work and regression analyses of Dr. Engel's sub-basins that he evaluated for the relationships between poultry house density and other variables. In such cases, if even a relatively small number of samples were compromised by poor quality assurance procedures, those errors could affect the results of analyses and validity of conclusions drawn from those analyses.

I am especially troubled by the report provided by CRA indicating that the sampling crews collected water samples from 1) springs that were not sampled at the location where they emerged to the ground surface, 2) spring sampling locations that were accessible to cattle, and 3) springs in which the sampling person stood (subsequent to walking across pasture land) in the water, thereby disturbing the sediment upstream from the sampling location, prior to collecting the water sample. Each of these issues has the potential to introduce substantial bias into the resulting data, thereby rendering the data indefensible, as explained below.

In his summary of the Plaintiffs' field sampling program for this case (Brown 2008, page 1-11), Plaintiffs' consultant Darren Brown defined a spring as:

> ***a place where the water table crops out at the ground surface and water flows out more or less continuously.***

He went on to say:

> ***The purpose of the [*spring*] sampling program was to collect reliable and repeatable data to evaluate the degree of groundwater contamination present in selected areas by sampling springs. The data were used to provide a preliminary evaluation of potential groundwater contamination."***

Despite the intended use of the spring water quality data (to evaluate *groundwater* contamination), and despite Mr. Brown's correct and appropriate definition of a spring as a place *where the water table crops out at the ground surface*, Plaintiffs' consultants collected at least one (one of four spring sample collections observed by CRA) "spring" sample from a streams at a location down-gradient from the place where the water table cropped out at the ground surface. Between the spring location and the point of sample collection, there would have been opportunities for fecal indicator bacteria and/or P to enter the surface water. Such contributions could have come from cattle, wildlife, domestic pets, fertilizer use, or other sources. In fact, in discussing this "spring" sample, CRA noted (Churchill 2008 , page 32):

> ***This surface water is a source of drinking water for pastured cattle, and cattle were observed in the vicinity of the sample location immediately prior to sample collection. Additionally, cow manure was observed on the ground near the water sample location.***

Defendants' expert, Dr. Jarman, reported results of field reconnaissance, conducted by Apex Companies staff during July, 2008, of Plaintiffs' spring sampling sites in the IRW. Dr. Jarman reported that the vast majority of Plaintiffs' spring sampling locations exhibited potential contamination of the spring by various sources of many of the same constituents that Plaintiffs' consultants analyzed for in their sampling program. These potential sources of sample contamination included probable road runoff, cattle access to stream, dog access to stream, proximity of house to stream, and others (Table 18-1). Therefore, Plaintiffs' "spring" data cannot be assumed to represent the quality of the groundwater.

A central problem here is that Plaintiffs' Standard Operating Procedures (SOPs) were inadequate and/or the field personnel employed by Plaintiffs' consultants were not sufficiently aware of the intended use of the data by the Plaintiffs for this case. As such, it was possible, or perhaps likely, that they might collect samples in such a way that the resulting data could not be used for their intended purpose. This same kind of problem was evident in Plaintiffs' edge-of-field sampling. Plaintiffs' staff apparently did not have a good understanding of what those samples were intended to represent, and therefore there was a high likelihood that the samples would be inadequate for their intended purpose. See discussion of edge-of-field problems in Section III.7.

If bacterial or nutrient analyses of spring water are intended to represent the quality of water as it emerges from the ground, thereby representing the quality of the groundwater itself, then the sample must be collected from the point where the spring surfaces from the ground. If there is opportunity for contamination of that water, after it emerges to the ground surface, from cattle, road runoff, fertilizer use, pets, other livestock, or wildlife prior to sample collection, then the sampled water cannot be expected to represent the quality of ground water. This is not a complicated issue. It is simply common sense. Plaintiffs' spring water data are represented by Plaintiffs as being indicative of the quality of the ground water, yet one or more spring samples were collected some distance down-gradient from the point at which the spring emerged to the ground surface and many of the spring sampling sites were found to be potentially subject to road runoff or had cattle access. Furthermore, Plaintiffs' consultants appeared to be confused about what constitutes an acceptable location for spring water collection. As documented by Jay Churchill (2008), Revision 3 of the Spring Sampling SOP, attached as an appendix to the Brown (2008) report, relaxed the requirements for spring sample site location after nearly all of the spring sampling had already been completed (55 of 57 samples had already been collected at the time of SOP revision). Specifically, the revision to the SOP changed the wording regarding an acceptable distance downstream from spring emersion for sample collection from:

> ***<u>shall</u> be no more than 200- feet downstream of the point where the water reaches the ground surface***

to a revised wording that stated that:

> ***the sample location <u>should preferably</u> be no more than 200-feet downstream of the point where the water reaches the ground surface*** (underline added for emphasis in both of the quotes given above)

There are several problems with this. First, an SOP is intended to serve as a guideline for sampling activities, not as an after-the-fact documentation of how sampling had actually occurred. Therefore, it makes no sense to revise the SOP after nearly all of the sampling had been completed. See more extensive discussion by Churchill (November, 2008) of this problem, which was apparently rather widespread. Second, wording such as "should preferably" is not helpful in an SOP; it only introduces confusion and increases the opportunity for errors in the field. Third, there is no downstream distance that is acceptable if the resulting spring water data are intended to represent the quality of ground water. This is especially true when there are cattle in the area between spring emersion and sample collection location. CRA observed Plaintiffs' sampling of four springs in 2006; they recorded evidence of cattle presence in the spring sampling location in three of those four springs. Dr. Jarman reported many more spring sampling sites that appeared to have cattle access (Table 18-1).

Sampling personnel must make sure that there is no likelihood of surface contamination of that spring sample from any surface-based contamination source, such as for example from cattle excrement. Cattle are important in this regard because they roam freely throughout pasture lands in the IRW and have direct access to surface waters (including both springs and streams) at some locations. Thus, where surface water that flows from a spring contains appreciable levels of P or fecal indicator bacteria, such constituents may be derived from the cattle if they are present at the time of sampling or in the recent past. CRA documented cattle access to some of Plaintiffs' spring sampling locations. For example, Churchill (November, 2008, page 30) noted cow manure several feet from where Plaintiffs' consultants collected one spring sample. At another location, cattle had been observed in the vicinity of the spring/surface water sample location. Sampling by Plaintiffs' field personnel of "spring" water samples at a distance down-gradient from where the spring emerged from the ground in an area frequented by cattle could not occur if those personnel had any idea of what the resulting data were intended to represent. It is unacceptable to collect a sample that you interpret as indicative of ground water quality at such a location. Again, this is simply common sense. Plaintiffs' consultant Dr. Fisher acknowledged in his September 2, 2008 deposition (page 586-587) that surface contamination can influence the quality of Plaintiffs' "spring" water that was collected some distance from the point of spring emersion from the ground, that many of the springs in the IRW are used for livestock watering, but that none of the Plaintiffs' spring samples were excluded from consideration because they may have been affected locally by animals or runoff directly to the spring location. This problem invalidates the spring data collected by Plaintiffs' consultants for this case.

An additional important issue that surfaced in conjunction with Plaintiffs' spring sampling is the level of training and oversight provided to Plaintiffs' sampling crew. It is never acceptable to stand in a body of water while sampling that water unless great care is taken to make sure that you are stepping and standing at locations that are clearly down-gradient from the point of sample collection so that you do not inadvertently contaminate the water before you collect it into your sample bottle. This is even more serious if you have walked across pasture land that may have been contaminated with fecal bacteria from cattle or other sources. You should never collect water from a point that is down-gradient from where you just stepped or otherwise disturbed the water or sediment. Documentation provided by CRA shows that such sample collection procedures were violated by the sampling crews dispatched by the State for this case. I observed a video showing an egregious violation of this sampling requirement. The field person collected the spring sample directly from the area that was impacted by the sediment disturbance. Such sloppy sampling procedures are completely unacceptable. It is noteworthy that this occurred when the sampling crew knew that they were being videoed. One can only imagine what occurred when the camera was not present. Given that the sampling personnel were not aware of the importance of such potential contamination issues, I have no faith that any of the data collected by these personnel could be used to assess the quality of ground water. I have no basis for evaluating what kinds of standard sampling procedure violations occurred when stream samples were collected, as none of those sampling events were captured on video. But given the nature of the procedural violations that I observed on the video clip and photographs and that were reported by CRA, Plaintiffs' consultants cannot demonstrate that their data are representative of field conditions in the IRW as they have interpreted them. Sample contamination problems are especially serious when analyzing for bacteria. For example, the rod-shaped *E. coli* species is only two millionths of a meter long (http://redpoll.pharmacy.ualberta.ca/CCDB/cgi-bin/STAT_NEW.cgi). Thus, it would take 40 *E. coli* placed end to end (the long way) to reach across the average width of a human hair (80 um). The volume of *E. coli* bacteria is so small that it would take a million billion of them to fill one 1-liter drinking water bottle. Because of their small size, and the large numbers present in animal and human feces, a very small amount of fecal contamination can yield concentrations in a water sample that are much higher than the 126 bacteria per 100 ml that is the primary body contact recreation standard.

Conestoga-Rovers and Associates did not observe any of the geoprobe sampling of groundwater in agricultural fields. However, they provided documentation to me that they did observe standard protocol violations in the collection of soil samples, and these included a range of potential contamination issues, the most serious of which were the collection of samples by driving the sampler through a cow pie, and visible cow manure on the sampler immediately prior to sample collection. In such situations, it is likely that the collected soil could be contaminated with material (most especially bacteria) present in the cow pie, and thus would not represent the condition of the soil below the surface. If similar breaches in protocols occurred when sampling groundwater using the geoprobe, then the resulting geoprobe data cannot be used to represent the quality of groundwater.

The contamination issues documented by Conestoga-Rovers and Associates are enormously important when assessing bacteria. A very small amount of contamination can result in an erroneous measurement of bacteria that is many-fold higher than any water quality standard.

Most sampling occasions for Plaintiffs' consultants' sampling program were not observed by CRA. I therefore do not know the extent to which these kinds of violations in acceptable sampling procedures actually occurred. Those that were documented, however, suggest to me that Plaintiffs' field personnel were not adequately trained, did not have proper oversight, and did not understand how the resulting data would be used. As documented by Churchill (2008, page 9), a tracking system was not employed by the Plaintiffs' consultants to document what training was received by the field personnel and no procedure was in place to re-train personnel when changes were made to the SOPs. Furthermore, there was not a Quality Assurance/Quality Control Project Plan (QAPP) developed by Plaintiffs' consultants in advance of the field sampling efforts (Connolly 2008, Churchill 2008). This is surprising, given the size, scope, and importance of the program. Perhaps if Plaintiffs' consultants had prepared and followed a QAPP, they might have avoided some of the serious sampling errors that were made.

19. *Existing federal and state guidelines and regulations were crafted to minimize the potential for surface water and ground water contamination as a consequence of spreading poultry litter on pastureland. To the best of my knowledge, Plaintiffs' consultants have presented no evidence to suggest that farmers in the IRW are not following those guidelines and regulations, or that those guidelines and regulations are not having their intended consequence (protection of water quality).*

Current poultry litter management regulations are designed to reduce the opportunity for P transport to streams by limiting surface runoff (litter not to be applied to areas that flood, in advance of a forecasted rainstorm, or on frozen soils) and limiting connectivity to the stream channel by requiring a setback buffer from the stream, an area to which poultry litter may not be applied.

The USDA and U.S. EPA created a joint strategy to implement nationally by 2008 comprehensive nutrient management plans (CNMPs) on animal feeding operations (AFOs) in the United States. Under this strategy, NRCS was charged with implementing a new nutrient management policy (Sharpley et al. 2003b). The planning standard (NRCS 590 Standard) was re-written to include P, as well as N. In each state, NRCS state conservationists selected one of three P-based management approaches: 1) agronomic soil test P; 2) environmental soil test P thresholds; or 3) P-Index to rank fields according to their vulnerability to potential P loss. The P-Index has been almost universally adopted, with 47 states selecting this approach to target P management (Sharpley et al. 2003b).

The indexing approach ranks field vulnerability to P loss by accounting for source (soil test P, fertilizer application, manure management), and transport (erosion, runoff, leaching, connectivity to a stream channel) factors. Additional factors that can be used as the basis for individual states modifying the basic approach can include flooding frequency, soil characteristics, conservation practices, and priority of receiving waters.

In 2003, the U.S. EPA revised the Confined Animal Feeding Operation (CAFO) regulations, which apply in part to poultry operations that have been designated as CAFOs. EPA designated (page 7196) that runoff from the application of CAFO manure, litter, or process waste waters to land that is under the control of a CAFO is a discharge from the CAFO and subject to National Pollutant Discharge Elimination System (NPDES) permit requirements, except where it is an agricultural storm water discharge

All permits for CAFOs must contain terms and conditions on land application in order to ensure appropriate control of discharges that are not agricultural storm water. These Federal regulations do not attempt to regulate agricultural storm water. EPA further stipulated (Pages 7197-7198) that:

> ***When manure or process water is applied in accordance with practices designed to ensure appropriate agricultural utilization of nutrients, it is a beneficial agricultural production input. This fulfills an important agricultural purpose, namely the fertilization of crops, and it does so in a way that minimizes the potential for a subsequent discharge of pollutants to waters of the U.S. EPA recognizes that even when the manure, litter, or process wastewater is land applied in accordance with practices designed to ensure appropriate agricultural utilization of nutrients, some runoff of nutrients may occur during rainfall events, but EPA believes that this potential will be minimized and any remaining runoff can reasonably be considered an agricultural storm water discharge***.

The revised CAFO regulations require preparation of CNMPs to govern land application of poultry litter. The agency stated (Page 7213) that:

> ***With imposition of the nutrient management plan requirement, there may be a large number of CAFOs that are all trying to develop plans at the same time. Yet, there is a limited pool of certified preparers and other technical experts that are available nationwide to develop nutrient management plans and CNMPs. It is reasonable to recognize that Large CAFOs (and Small and Medium CAFOs), along with AFOs, could be competing for the services of the experts. EPA estimates there are approximately 15,500 CAFOs, including 11,000 Large CAFOs, and 222,000 AFOs. AFOs are not required to prepare CNMPs, but their access to sources of public funds, such as EQIP, may be contingent on their adherence to NRCS technical standards, including preparation of a CNMP. Thus, additional time is needed for development and implementation of the plan. Another aspect that prevents CAFOs from immediately complying with the land application BMPs is the need for States to ensure that they have established appropriate technical standards that CAFOs will use to determine the appropriate application rates for their fields. These standards must be a part of the State NPDES permitting program revisions discussed in Section V.C of this preamble. In addition, CAFOs will need some time to determine whether they have sufficient cropland for applying all of the nutrients contained in the manure, litter, and other process wastewaters that they generate. If they determine that they have excess nutrients, the CAFOs will need to identify alternatives for reducing the nutrient content, or seek markets for the excess nutrients such as off-site cropland, centralized processing facilities (e.g., pelletizing plants, centralized anaerobic digester-based power generation facilities), or other solutions. These activities cannot logically commence until the CAFO has developed the plan and knows what its allowable manure application rate is.***

Thus, EPA recognized that it takes time to implement substantial changes in regulations regarding nutrient management on lands to which poultry litter is applied. In fact, EPA subsequently delayed further the date on which the new regulations would take effect, to provide additional time beyond the intended December 31, 2006 start date. In further clarifying the timing of these changes, EPA stated (Page 7214):

> ***While EPA believes that the requirement to develop and implement a nutrient management plan will be an ''available'' technology in the near future, it is not now available for the large number of CAFOs subject to today's rule. For this reason, EPA is, in essence, today promulgating what will be the available technology for the future, similar to what the Agency did for the pulp & paper effluent guideline. See 63 FR 18604 (Apr. 15, 1998). EPA is specifying the future date of December 31, 2006 because that is the date by which it predicts that sufficient capacity and capability to develop and implement a nutrient management plan and associated BMPs will be available to the great number of regulated sources. The availability of technical experts, including certified preparers, is a critically important component of the planning requirement.***

EPA considered, but did not accept, a potential requirement for CAFOs to sample surface (i.e., stream) water above and below land application areas, in part because they recognized that there exist other, non-CAFO sources within the agricultural areas. EPA stated (Page 7217):

> ***At the time of proposal, EPA considered, but rejected, requiring CAFOs to sample surface waters adjacent to feedlots and/or land under control of the feedlot to which manure is applied. This option would have required CAFOs to sample surface waters both upstream and downstream from the feedlot and land application areas following significant rainfall. In this final rule, EPA is continuing to reject imposing surface water monitoring requirements on CAFOs through the effluent guidelines because of concerns regarding the difficulty of designing and implementing through a national rule an effective surface water monitoring program that would be capable of detecting, isolating, and quantifying the pollutant contributions reaching surface waters from individual CAFOs; and because the addition of instream monitoring does not by itself achieve any better controls on the discharges from CAFOs than the controls imposed by this rule. In-stream monitoring could be an indicator of discharges occurring from the CAFO; however, unless conditions are appropriate and a well-designed sampling protocol is established, it is equally possible that the in-stream monitoring considered at proposal would measure discharges occurring from adjacent non-CAFO agricultural sources. These non-CAFO sources would likely be contributing many of the same pollutants considered under the sampling option.***

Plaintiffs' consultants largely ignore these additional sources that occur in proximity to poultry operations and the lands to which poultry litter are applied.

In addition to the federal rules promulgated by EPA under the CAFO program, there are also state regulations and guidelines governing land application of poultry litter. Regulations have been put into place in Oklahoma and Arkansas in recent years in response to concerns about agricultural soils containing high concentrations of P. In Oklahoma, the NRCS Code 590 is the basis for the regulations. Arkansas uses a P Index to mitigate the potential for agricultural contributions of P to drainage waters. Plaintiffs' consultant, Berton Fisher, acknowledged that land application of poultry litter in the IRW is subject to the rules and regulations of Oklahoma and Arkansas (September 4, 2008 deposition testimony, page 473). He also acknowledged that, even though Plaintiffs' consultants had employed a team of observers to drive through the IRW and examine poultry operations, he was not aware of any circumstances where poultry litter has been applied in the IRW in violation of the provisions of that landowner's nutrient management plan or animal waste management plan.

Nutrient management plans are prepared to govern land application of poultry litter. They include provisions that are intended to minimize conditions that favor transport of P or fecal indicator bacteria to streams and/or to ground water.

Existing regulations and guidelines include avoidance of land application of poultry litter in pasture areas and under conditions that would be expected to increase the likelihood of either surface water or ground water contamination with some of the constituents in poultry litter, especially P and fecal indicator bacteria. The following conditions are avoided:

- Fields having high P content in the soil
- Areas that frequently flood
- Areas near a stream
- Frozen or water-saturated soil
- Shallow or rocky soil
- Steep slopes.

In addition, plans for nutrient management are developed under specific technical guidelines. Soil sampling and laboratory analysis is conducted in accordance with land grant university guidance or industry practice.

Within the pasture/hay land use areas in the IRW, soils are generally loamy. Less than 1.6 percent of these soils are classified in the USDA NRCS Soil Survey Geographic Database (SSURGO), as "clay" soils, the general class of soil particle size distribution which would be expected to promote overland flow. In addition, less than 4% of these pasture/hay soils are expected to be less than 10 inches deep, according to the average depth as reported by SSURGO. This is the depth identified by the Oklahoma NRCS Code 590 as too shallow for land application of poultry litter.

The Arkansas NRCS Code 590 (December 2004) specifies that manure shall be applied at rates to meet crop P needs when the P Index rating is High, and there shall be no manure application on sites with P Index rating of Very High. Manure application is not to occur on sites considered vulnerable to off-site P transport unless appropriate conservation practices, best management practices or management activities are used to reduce the vulnerability to P runoff. In areas with identified nutrient-related water quality impairment, an assessment shall be completed of the potential for P transport using the P Index. The results of this assessment shall be included in the nutrient management plan. Nutrient applications shall consider minimum application setback distances from environmentally sensitive areas.

Chapter 9 of the Arkansas Nutrient Management Planners' Guide (Daniels et al. Undated) provides an overview of nutrient planning in Arkansas. This document describes several sets of regulations that require livestock operations to implement plans. These include: 1) Arkansas

State Regulation 5, implemented in 1994, that requires nutrient management plans for poultry operations that had liquid manure handling systems, 2) the U.S. EPA's Confined Animal Feeding Operations (CAFO) regulations that require the states to permit CAFOs of given size, 3) Arkansas Acts 1059 and 1061 that identify nutrient sensitive areas in the state and require all nutrient applications to be done according to a nutrient management plan, including a litter management plan for poultry operations with at least 2,500 birds. Manure application rates are determined using the P Index. Setback distances are described by Daniels et al. (Undated) as follows:

> ***Dry litter applications are governed by State Title 22 as administered by ASWCC and by the Federal CAFO rules. Nutrient management protocol for Title 22 is the NRCS Standard 590 for the State of Arkansas. While Standard 590 does not specifically state setback distances, it does refer to two other NRCS standards, 633 Waste Management and 393 Filter Strips, that specifically state distances. In both cases, distances are dependent on the slope of an area next to a critical water feature (Table 9-2 and Table 9-3).***

The setback distances given in the two tables referenced above vary with slope classes and range from 20 ft for slopes less than 2% to 100 ft for slopes greater than 8% or for critical landscape features such as springs, sink holes, wells, and rock outcrops.

The Oklahoma NRCS Code 590 specifies that manure shall not be applied under the following conditions:

- areas within 100 feet of a perennial stream or pond or within 50 feet of an intermittent stream unless an established buffer strip is present that meets NRCS requirements for design and maintenance,
- areas within 100 feet of a well or sinkhole,
- fields steeper than 15% slope,
- shallow soils (less than 10 inches depth),
- rocky soils,
- soils that are frequently flooded,
- soils that are frozen, snow covered, or water saturated,
- eroding soils.

These guidelines are intended to reduce the likelihood of surface water or ground water impacts from the land application of poultry litter. They are based on current scientific understanding that recognizes that both source and transport issues are important in nutrient management. When farmers follow these guidelines, they are complying with existing laws and with current scientific understanding regarding management of NPS pollution.

Plaintiffs' consultants did not consider the extent to which existing laws and guidelines in Oklahoma and Arkansas that govern land application of poultry litter actually affect the possibility that some of the key constituents in poultry litter will move from pasture to stream. In fact, Plaintiffs' consultants totally ignored this issue. During his September 4, 2008 deposition, Berton Fisher was asked:

> ***how did the Code 590 and the state's laws on litter application factor into the forming of your opinions?***

Dr. Fisher responded:

> ***Well, I think that's accurate. They are not relevant.***

Dr. Fisher testified (pages 496 and 497) that the USDA NRCS, which drafted the Code 590 regulations, and the scientists and technicians who prepare animal waste management plans and nutrient management plans that tell farmers where, when, and how much poultry litter they can land apply in the IRW are wrong or provide guidance that is inappropriate. Dr. Fisher apparently would have the court believe that his judgment regarding land application of poultry litter should be accepted over these groups of professionals. But he provided no justification for his position that current state and federal guidance regarding land application of poultry litter is in error. He also failed to provide justification for Plaintiffs' position that land application of poultry litter, when done in accordance with current state and federal guidance, causes harm to streams in the IRW or to Lake Tenkiller.

The P-Index approach provides farmers with flexibility, giving them options for reducing the likelihood that P will move from their fields to a nearby stream. For example, Sharpley et al. (2003b) demonstrated that overall P index ratings can be decreased (lower risk of P movement to stream) by implementing specific management changes, such as changing the time of manure application, establishing riparian buffers, or reducing the feed P ration. These kinds of management actions give farmers more options, in the process of managing P transport to streams, than just reducing manure application rates (Sharpley et al. 2003b).

There are two main objectives in agricultural nutrient management: to protect water quality and to protect agricultural production and livelihoods. These two objectives jointly determine nutrient management policy. Plaintiffs' consultants ask the court to consider their misguided attempts to protect water quality, and to ignore the importance of protecting agricultural production and livelihoods.

20. *Based on examination of various reports and testimony of Plaintiffs' consultants in this case, they apparently set out to try to prove that poultry litter spreading is the cause of stream and lake pollution in the IRW. They failed to adequately consider the multitude of human activities and land uses found in the IRW that are known to be important sources of point and nonpoint pollutants to surface waters.*

There are many examples where Plaintiffs' consultants lump what is undoubtedly multiple pollutant sources into what they label as poultry-derived pollution. They minimize the influence of other known sources of point and nonpoint pollution of stream water. Thus, their analyses in many cases are not representative of the relative importance of the various potential sources of P and fecal indicator bacteria in the IRW. Rather, their effort appears to be biased so as to maximize the perceived importance of nonpoint, as compared with point, source pollution that they then attempt to assign without adequate basis to poultry operations. The study conducted by Plaintiffs' consultants for this case does not represent an objective evaluation of the relative importance of the various potentially important sources of P and fecal indicator bacteria to stream water throughout the IRW and to Lake Tenkiller. Numerous previous studies and assessments of water quality in the IRW consistently recognized the complexity of the water quality issues in this watershed and the importance of multiple potential pollution sources, in agreement with the body of scientific literature on point and nonpoint source water pollution in general. Plaintiffs' consultants ignore this literature in their efforts to exaggerate effects on water quality in this watershed and to cast blame on one industry for what is clearly a very complex water quality concern.

There are many examples of bias in the sampling and analysis efforts of the State's consultants. There was not a consistent effort to stratify sampling sites or data analyses according to the influence of WWTP outflows and/or urban development, which are expected to be the main source of point source pollution (WWTPs) and one of the main sources of nonpoint source pollution (urban runoff) within the watershed.

Much of the stream sampling effort was focused on small tributary streams. The waters in the IRW that provide the foundation for most of the recreation, offer the greatest possibility of human exposure to fecal indicator bacteria, and provide the loading of nutrients and other constituents to Lake Tenkiller are generally not small tributary stream water. Rather these are waters from the larger 5^{th} and 6^{th} order streams, such as the mainstem Illinois River, mainstem Baron Fork, and lower Flint Creek. The State's focus on small tributaries serves to support an attempt to assign blame to poultry operations rather than to conduct an objective assessment of the relative importance of the various sources of water pollution that exist within the basin.

There are many other examples of this type of bias. For example, Dr. Olsen selected 27 subwatersheds for study across a range of poultry house densities (Olsen 2008, page 2-11), rather than across a range of NPS pollution sources of all types. Therefore, his sites are not representative of the portions of the IRW in which NPS pollution is most important to lake conditions and recreational usage. Subwatershed selection was structured to maximize the influence of land use that Dr. Olsen interprets as being indicative of poultry waste contributions. There were not parallel attempts to examine the influence of cattle, urban runoff, land application of swine manure, land application of biosolids, septic systems, or wildlife. Drs. Engel and Stevenson structured some of their analyses so as to delete from consideration subwatersheds that contained appreciable urban influence and point source contributions of water pollution without acknowledging the narrow scope of the subsequent analyses. Thus, they excluded point sources (clearly major sources in the IRW), excluded nonpoint urban sources and then labeled all the remaining NPS sources as "poultry", despite the fact that those remaining potential NPS source locations include cattle, septic systems, erosion, wildlife, fertilizer, and other livestock.

On page 6-1, Dr. Olsen states that the purpose of Section 6 of his report was:

> ***to evaluate and document a link (if any) between poultry land waste disposal and environmental contamination in the IRW.***

He goes on to claim that he had a second objective to evaluate other potential sources of environmental contamination, and that his sampling schemes and evaluations were designed so that all major sources of contamination would be identified. However, Dr. Olsen did not collect the samples that would be necessary to accomplish that second objective.

Dr. Stevenson, in his report for this case (2008, page 13) described how sites were selected for his biological and chemical studies in summer 2006, spring 2007, and summer 2007 as follows:

> ***…sampling sites were selected randomly from 5 groups of potential sampling sites (the strata). Potential sampling sites were assigned to these 5 groups based on poultry house density and geographic location in the IRW."***

There was no effort to stratify sampling sites according to cattle use, residential housing density, or any other variable that might reflect different levels of NPS contribution to streams. The study was designed to attempt to assign blame to the poultry industry, rather than to conduct an objective assessment of point and nonpoint sources in the watershed.

Plaintiffs' consultant, Darren Brown acknowledged in his August 26, 2008 deposition (transcript, pages 85 to 93) that he was not aware of any samples collected by the Plaintiffs of the following types:

- Runoff from golf courses
- Soil samples from golf courses
- Cattle or dairy waste lagoons
- Soil samples from confined cattle feeding operations
- Lands where manure from dairy cattle had been land applied
- Edge of field runoff from lands where manure from dairy cattle had been land applied
- Samples associated with swine operations
- Samples associated with sewage releases
- Soil samples in areas associated with septic systems
- Samples taken to evaluate the constituents in water running off a road
- Samples of urban stormwater runoff
- Soil samples from fields fertilized with commercial fertilizer
- Edge of field samples from fields fertilized with commercial fertilizer

Mr. Brown further testified (transcript, page 93) that:

> ***The investigation that was conducted during this program was not intended to be a full assessment of the Illinois River Watershed.***

Dr. Stevenson stated in his January 8, 2009 deposition (transcript page 340) that he selected study sites for his analyses of fish specifically to remove urban impacts:

> ***Well, there are 37 total sites, and I reduced the analysis to 22 because to remove – basically, I used that same rule to reduce the effect of urban activities on the sampling sites, so used over half. I wanted to make sure that urban activities didn't have an effect and that we could isolate the possible correlations, causal pathway associated with the poultry.***

On page 341 of his deposition transcript, Dr. Stevenson further stated that in his sample site selection, he wanted to have as many sample sites as possible, but as low of urban impact as possible.

On page 2-23, Dr. Olsen states (2008) that the primary focus of his river sampling effort was to determine the effect on resources in the IRW of the land application of poultry litter. No statement was made regarding any focus on the relative importance of poultry litter compared to other known sources of pollution. He attempted to

> ***document a link between various water quality parameters… and compare the analytical results with chicken house density and poultry waste application***

irrespective of the extent to which poultry house density and/or poultry waste application might themselves be linked with other human activities known to contribute NPS pollution.

Dr. Harwood described her role in this case (Preliminary Injunction hearing transcript, February 21, 2008, page 780):

> ***It was my job to determine whether or not there's a correlation between the practices of land applying the poultry litter and the contamination that's appearing in streams. That's how I would phrase it.***

Similarly, Dr. Stevenson (2008, page 1) based his conclusions on:

> ***extensive studies of IRW streams that were designed to evaluate and document the resulting harm/injury to natural systems that has resulted from the disposal of poultry wastes within the IRW.***

Dr. Olsen collected what he termed edge-of-field samples, and interpreted those samples as being indicative of water flowing from litter-amended fields into streams. Yet he offers no evidence that the water from those edge-of-field locations actually flows from a field or into a stream. He simply assumes that these flow patterns occur.

Dr. Olsen also offers data from samples that he labels as "spring samples", but that were actually collected from a ***stream*** that received flow from a spring, and that stream had flowed in the interim (between the point of spring emersion from the ground and point of sample collection) across land that may have provided various NPS pollutants, especially from cattle access to the sampling location. Dr. Olsen's field staff also collected samples from other springs to which cattle had access or which may have received runoff from lands subject to other human and livestock influence. Thus, any pollutants found in that spring or stream water were interpreted by Dr. Olsen, without basis, as representing pollutants in groundwater, and he attributed those pollutants to poultry litter spreading, without consideration of other possible local sources.

It appears that Dr. Olsen's field sampling was generally structured in such a way as to reveal the water quality at the time when it was worst. For example, river samples were collected between 4:00 am and 9:00 am:

> ***"in order to document the lowest dissolved oxygen conditions at each location."***

Thus, the data collected by Plaintiffs' consultants were not representative of overall conditions. As Dr. Olsen acknowledges, samples were collected with the express purpose of documenting the most extreme conditions possible.

Plaintiffs' consultant, Darren Brown (Report submitted May 15, 2008, page 1-2) summarized the Plaintiffs' field data collection program for this case and stated the following :

> ***The purpose of this document is to present a summary of the field investigation efforts associated with the Illinois River Watershed 2005 through 2008 field investigations…The field investigation program was conducted to investigate and document the links between the application of poultry waste on the fields within the Illinois River Watershed and the impacts on the soils, sediments, groundwater, surface water, and aquatic biology within the watershed."***

There are also numerous examples of site selection that either advertently or inadvertently cast blame on poultry litter application as the pollution source, when in fact there were other obvious pollution sources that were ignored. These include edge-of-field samples collected adjacent to a housing development, spring samples collected in close proximity to rural housing, spring and edge-of-field sample sites with cattle access, stream sampling sites with flow backup into floodplain areas, and many others. Data from such locations were interpreted by State's consultants as evidence of water contamination with constituents from poultry litter. In fact, there is no basis for assigning contaminant sources to water samples collected at such locations.

Plaintiffs' consultant, Dr. Stevenson testified in his deposition (January 8, 2009, page 104) when asked about a conversation with Plaintiffs' attorney Mr. David Page, that he was told that the focus of Plaintiffs' efforts was on what they termed damages related to contamination of the watershed by poultry. The following exchange is recorded in the deposition transcript:

> ***Q. Will you read the highlighted E-mail?***
>
> ***A. Yea. I talked with David… He encouraged us to call(ed) David Boyle to get his input. If we can't show how a metric measurement gives us a damage number, he really does not want to measure it.***
>
> ***Q. What do you understand that to mean?***
>
> ***A. I understand that to mean that he does not want us to be measuring information that would not be related to damages. That this was related to a conversation that we wanted to more specifically develop a causal framework and come up with end points that would be related with aesthetics and biological condition damages.***
>
> ***Q. Damages by what, caused by what?***
>
> ***A. Damages related to contamination of the watershed by poultry. That was the hypothesis that we tested.***

Later in his deposition (transcript page 152), Dr. Stevenson further testified:

> ***So the goal was to test the null hypothesis that poultry houses effects were not affecting the ecology, phosphorus concentrations, algae, the ecology of the streams, down to the assessment end points.***

For that reason, Dr. Stevenson selected (Deposition transcript, page 152) his stream subwatersheds throughout the IRW according to poultry house density:

> ***…we wanted even numbers of sites in low poultry houses, high poultry houses, and we decided to have five different levels of poultry houses in between so that we'd end up with sites all along our independent variable axis, which was poultry houses, our ultimate independent axis.***

21. *There is an entire field of study on factors that regulate P loss from pasture lands. Current scientific understanding reveals that P loss from fields to surface waters is controlled by a variety of factors that affect the sources of P in the field and the transport mechanisms available to move the P from source locations to streams. This research provides the foundation for current poultry litter management in the IRW. Plaintiffs' consultants ignore this body of scientific research.*

There is a large body of scientific knowledge on the potential for P to move from litter-amended pasture land to stream water. This field of research includes a large number of publications and a variety of approaches focused on field-scale assessment of risk of P movement from field to stream in runoff (www.sera17.ext.vt.edu).

More than 15 years ago, the U.S. Department of Agriculture began to develop field-scale assessment tools to assess the potential movement of P from field to stream. A group of scientists from government agencies and universities formed the Phosphorus Index Core Team (PICT) to develop a Phosphorus Index to assess the relative risk of P movement (http://www.sera17.ext.vt.edu/index.htm). The working group evolved into what is now known as SERA-17, which is a USDA Information Exchange Group, focused on P management for water quality protection. SERA-17 has published a number of policy workgroup reports and best management practice factsheets to address various aspects of this research field. Included among these is a position paper on phosphorus indices to predict risk for phosphorus losses. This position paper (available on the SERA-17 web site given above) discusses the concepts and science behind P indices. In the P index approach, best available scientific knowledge about field-scale processes is put together to produce one index score reflecting the potential for P movement to streams from a particular field. It takes into consideration both the source and the transport of P to yield a comprehensive assessment of the risk of P loss in runoff from the site. To date, at least 47 states have adopted the P index approach by modifying the basic components to fit local conditions. This adoption of the P index concept by at least 47 states illustrates the consensus among scientists, industry, and policy makers in the United States that such an integrated approach is appropriate ((Sharpley et al. 2003b).

Most P indices include a variety of data, such as soil test P, fertilization or manure/litter application rates, method and timing of application, soil erosion, and distance from field to stream. According to this SERA-17 position paper:

> ***If a source of P exists at a particular field (such as high soil test P, or recent fertilizer or manure applications), but there is no significant transport pathway for this P to leave the field and enter a stream, then the site does not represent a high risk for environmental P loss. Similarly, if there is a high risk of transport from a site (such as moderate runoff and/or erosion), but there is no large source of P at the site (i.e., low soil test P, or only small or no applications of fertilizer and /or manure), this site also will not represent a high risk for P loss. This is the basic concept of all P Indices, they identify two important categories***

> ***that can generally be defined as 'source' and 'transport' factors for P loss, which together identify critical source areas (Sharpley et al. 1993).***

Plaintiffs in this case ignore the scientific foundation represented by SERA-17, which has developed from a coordinated effort by the U.S. Department of Agriculture and university scientists. Plaintiffs ask the Court to set aside guidelines and regulations for litter application that are based on these scientific principles, and substitute Plaintiffs' consultants' view of how P management should be implemented. In essence, Plaintiffs' consultants assume without basis that most P contributed to streams in the IRW is contributed from land application of poultry litter, and they also assume that all pasture lands to which poultry litter is applied have an equal probability of causing movement of P from pasture to stream.

All P indices were developed and modified using the best available professional knowledge. The principles have been well documented in the scientific literature. For example, the North Carolina version of the P Index lists about 150 scientific publications in its supporting literature (see SERA-17 position paper). In this case, Plaintiffs fail to recognize that current State and Federal guidelines and regulations already address both P source and transport issues. In contrast, Plaintiffs' consultants generally ignore transport, and instead rely on their edge-of-field samples to evaluate risk of P movement to streams. However, as described more fully in Section III.7 of this report, those edge-of-field samples ignore obvious P contributions from point sources and urban areas, provide no basis for discriminating among potential P sources in the non-urban landscape, do not document transport pathways, and do not determine the likelihood of eventual movement of P into streams.

The implicit assumption by Plaintiffs' consultants that transport processes are unimportant ignores the last 15 years of research. There is no scientific basis for assuming that all, most, or even a substantial fraction of the fields to which a P-containing material (poultry litter) is applied represent a threat to stream water quality. If there are fields or portions of fields in the IRW that do represent a threat (largely the hydrologically active areas), Plaintiffs' consultants have failed to identify them and current regulations and guidelines are structured to minimize the threat to water quality from such areas by preventing the application of poultry litter to such areas.

In order to understand the potential for P movement from pasture land to stream, it is critical to consider both source and transport issues. Although there are models available to aid in the integration of this information, there are serious questions about the reliability of such models if they are not tested and confirmed using site-specific data.

Radcliffe and Nelson (Undated) summarized the position of SERA-17 on predicting P losses from edge-of-field and modeling efforts. They stated:

> ***Even at these scales (field and annual), there are gaps in our scientific knowledge about P processes, be they implemented in P indices or dynamic models.***

The authors went on to say:

> ***In our opinion, watershed-scale predictions of loadings to lakes are not reliable unless extensive, site-specific calibration is used. The same can be said for short-term (daily) predictions at the edge-of-field scale. These types of predictions remain in the research development stage. The capability to make predictions at this scale is, however, an appropriate long-term goal.***

They cautioned that when models are used in a regulatory capacity, because of the potential for model results to cause direct economic harm on individual producers, these:

> ***models should undergo additional validation and subsequent refinements prior to regulatory application.***

Plaintiffs' consultants did not conduct such validation exercises. In fact, measured values of P concentration in edge-of-field samples and stream samples at the hundreds of locations that Plaintiffs' consultants sampled in their field efforts for this case were never used to constrain or evaluate Dr. Engel's watershed modeling. Results of Dr. Engel's routing model application were only compared with stream water quality data collected at the bottom of the watershed, near Lake Tenkiller. See further discussion of this issue in the expert report prepared by Defendants' expert, Dr. Bierman. Dr. Engel applied a flawed approach when developing his model (Bierman 2009). Therefore, it would be possible for Dr. Engel to obtain a good fit between his modeled values and the measured values of TP at these downstream locations irrespective of whether his GLEAMS model estimates that he developed for the upper reaches of the watershed were correct, or were representative of the various potential sources of P across the landscape that Dr. Engel attempted to model.

22. *Plaintiffs' consultants provide no convincing evidence to indicate that land application of poultry litter is an important source of P and fecal indicator bacteria to streams in the IRW. To the best of my knowledge, Plaintiffs' consultants do not provide a single example of transport of P to stream water from land application of poultry litter in a comparable field setting and set of litter application guidelines under normal rainfall regimes, either within the IRW or anywhere else. Examples of small plot experimental treatments that involved artificial rainfall at intensities that seldom occur in the IRW (for example, Edwards et al. (1995), Daniel et al. (1995) are not representative of typical field conditions and therefore are of minimal relevance to water quality issues within the IRW. Such studies merely illustrate that, if it rains with a sufficient intensity (typically greater than or equal to 5 cm/hr [about 2 inches per hour]), it is possible to generate overland flow on some soils and therefore contribute P from soil to down-slope stream waters at those specific locations. Such studies have been valuable scientifically to improve understanding of P dynamics in simulated field settings, but they cannot be used to justify Plaintiffs' consultants' claims that under normal rainfall regimes in the IRW, an appreciable amount of P is transported in overland flow from litter-amended pastures to streams. First of all, it is quite possible that some overland flow might occur in certain areas, and subsequently that water may infiltrate into the soil lower on the hillslope, removing dissolved P from the water before the water reaches a stream. But most importantly, it simply does not rain in the IRW with such a high intensity on any except the rarest of occasions.*

Many of the datasets used for development of models and study of P transport mechanisms have been produced under artificial simulated rainfall (Edwards et al. 1995, Sauer et al. 2000, Kleinman et al. 2002, Radcliffe and Nelson 2005). However, the predictive relationships developed from simulated rainfall are not necessarily transferable to natural conditions. Radcliffe and Nelson (2005) concluded:

Because of the differences between P losses observed under simulated rainfall vs. natural rainfall, models should be validated with datasets derived from natural rainfall studies.

Published experimental studies that relied on simulated artificial rainfall to determine movement of P from fields amended with poultry litter typically applied artificial rain at intensity equal to 5 cm/hr or higher. Based on data from the National Climatic Data Center (Table 11-1), it seldom rains in the IRW with such intensity. Thus, results of these experimental studies are not directly applicable to questions regarding the extent to which P may move off pastures to which poultry litter had been land applied and into streams in the IRW.

I examined hourly precipitation data available for the IRW over the period from 1949 to 1997 for Tenkiller dam (at the bottom of the watershed) and from 1966 to 2008 for Fayetteville, Arkansas (at the top of the watershed). During only 0.05 % to 0.07% of the hours for which rainfall was recorded at these two monitoring stations (six individual hours at each station over a period of record of more than 40 years at each site) was the hourly rainfall intensity higher than 5 cm per hour (1.97 inches per hour). Only 0.1 percent of the hours for which rainfall was recorded exhibited hourly rain intensity higher than 1.7 inches per hour. On average, only during one hour out of every seven or eight years was the measured precipitation greater than 1.97 inches (2 cm). Thus, the publications cited by Plaintiffs' consultants, in support of their contention that P runs off pasture lands subsequent to land application of poultry litter, are not directly relevant to Plaintiffs' consultants' claims to the extent that these publications employed artificial experimental rain application at rates higher than commonly occur in the IRW.

Plaintiffs' consultants contend that one factor (land application of poultry litter) is the predominant cause of water quality impairment in the IRW. Plaintiffs' consultants offer no scientifically defensible evidence in support of that contention. Due to the large numbers of people and livestock (especially cattle) in the IRW, and as is indicated in the available data for the watershed and the body of scientific information on watershed sources of stream water pollution in general, it is clear that there are multiple sources of point and nonpoint contributions of P and fecal indicator bacteria to surface waters in the IRW. Plaintiffs' consultants offer no scientifically defensible evidence that land application of poultry litter is important in that regard. They certainly provide no scientifically defensible evidence that land application of poultry litter constitutes the dominant source. In contrast, stream water quality data collected by Plaintiffs' consultants for this case illustrate that P concentrations in stream waters in the IRW largely originate in and around urban areas and WWTP facilities.

With regard to potential bacterial contamination of water in the IRW, Defendants' expert Dr. Herbert DuPont concluded (2008, page 19) that Plaintiffs focused only on poultry as the potential source of environmental contamination, and that they made a non-scientific decision to pursue the poultry industry ignoring all other sources of contamination. Cattle are known to harbor and excrete into the environment bacterial pathogens that can cause human disease, including strains of pathogenic *E. coli*, *Cryptosporidium*, and *Salmonella*. Wildlife regularly add fecal indicator bacteria to stream water (Myoda 2008). Dr. DuPont reviewed studies indicating that the three most important sources of bacterial contamination of water in the United States are people, cattle, and wildlife. Plaintiffs' consultants ignored these, and assumed that human pathogens were present in the IRW even though they generally did not find them, and further that these pathogens that they did not find were contributed by poultry.

The primary approaches offered by Plaintiffs' consultants in their efforts to assign responsibility to the poultry industry for P that occurs in streams in the IRW are: 1) the edge-of-field water quality data, 2) Dr. Olsen's PCA analysis and 3) results of GLEAMS modeling by Dr. Engel. The edge-of-field data reveal nothing about specific sources of P beyond what Plaintiffs' consultants **assume**; similarly, edge-of-field data do not indicate that any of that water sampled at the edge-of-field (and at the edge of roads and along ditches) actually moved to any stream. As described more fully in other sections of this report, Dr. Olsen's PCA was not able to discriminate among the potential sources of P to stream waters in the non-urban portions of the watershed. The GLEAMS modeling relied on a totally empirical routing model to estimate the contribution of various potential sources to the upper end of Lake Tenkiller. As shown by Dr. Bierman (2008), varying model inputs can yield acceptable model estimates of P concentrations in stream water at the inlet to Lake Tenkiller. The model calibration demonstrated by Dr. Engel does not confirm that the parameters that he used in his model to apportion P sources are correct or even reasonable.

Radcliffe and Nelson (2005), in their position paper for SERA-17, summarized the group's position on watershed-scale modeling of P loading as follows:

> ***In our opinion, watershed-scale predictions of loadings to lakes are not reliable unless extensive, site-specific calibration is used. The same can be said for short-term (daily) predictions at the edge-of-field scale. These types of predictions remain in the research development stage. The capability to make predictions at this scale is, however, an appropriate long-term goal.***

As discussed by Dr. Bierman, in his expert report for this case (January, 2009), Plaintiffs' consultants did not provide site-specific calibration for their modeling effort anywhere except at the bottom of the watershed. As a result, they cannot scientifically defend the conclusions they draw from their model results with respect to sources of P within the watershed. Neither plaintiffs' edge-of-field data nor their stream data from sites scattered throughout the watershed were used to constrain their GLEAMS model calibration. Radcliffe and Nelson (2005, page 4) went on to say, in discussing the use of field-scale P loss model predictions to regulate individual farmers or producers, :

> ***caution must be used when models are applied for these expanded purposes. For example, because of the potential for model results to inflict direct economic harm on individual producers, models should undergo additional validation and subsequent refinements prior to regulatory application.***

The models applied by Plaintiffs' consultants in this case did not undergo such validation and refinement.

Dr. Harwood claims that she can identify the origin of fecal indicator bacteria that she finds in Lake Tenkiller (or elsewhere in the IRW) on the basis of the number of small pieces of bacterial DNA that she finds in the water. Her analyses **assume** that other bacteria (such as for example a fecal indicator like *E. coli* or potential pathogens like *Salmonella* or *Campylobacter*) will move along the same pathways (from source location through and over soils, through ground surface vegetation, and through stream systems, past potential predators and life-threatening conditions (sunlight, heat, drying, etc.) and finally arrive at her sample location) at the same rate and in the same proportion as her presumed *Brevibacterium avium*. There are many problems associated with having to make such assumptions. First, bacteria are different shapes and will therefore move through soil spaces at different rates. Second, bacteria are extremely small and the size of a single piece of bacterial DNA is much smaller than the entire bacterium from which it is extracted. For example, the length of *E. coli* is one-fortieth the width of the average human hair. The DNA of *E. coli* occupies only 1% of an *E. coli* bacterium (http://redpoll.pharmacy.ualberta.ca/CCDB/cgi-bin/STAT_NEW.cgi). One of the DNA segments that Dr. Harwood uses as a tracer is only a fraction of the length of the bacterial DNA. Thus it is obvious that Dr. Harwood is dealing with very tiny pieces of genetic material that cannot be assumed to move through the environment in the same way or at the same rate as living bacteria of that species or any other. Third, fecal indicator bacteria stick to soil surfaces, and this stickiness is partly a function of the properties of the outside of the bacterial cell surface. The surface of a living bacterium is not the same as the surface of a non-living piece of bacterial DNA. Dr. Harwood has not provided documentation that her tiny gene sequences move through the watershed to the same extent as do the living bacteria. Fourth, Dr. Harwood does not provide data to indicate how long her pieces of bacterial DNA persist in the environment. She made a general statement in her July 18, 2008 deposition (transcript page 12) that bacterial DNA may remain in the environment for a period of hours to several days. Living bacteria are capable of affecting humans only while they remain viable. Dr. Harwood provides no evidence that pieces of bacterial DNA can have any adverse effect on humans or any other species. In addition to these problems with respect to Dr. Harwood's assumptions about bacteria movement, it is also important to note that Dr. Harwood has not done any analyses that would shed light on the movement of P in the IRW.

Control of NPS water pollution requires first that one recognizes that there are multiple NPS sources. With that recognition, it is possible to implement a variety of BMPs that can effectively reduce the concentration of P and other constituents in stream water. This has been well demonstrated for one watershed within the IRW, as documented by Haraughty (1999). Oklahoma's first CWA Section 319(h) project was a demonstration of BMP effectiveness in the Battle Branch watershed over a three-year period. Public participation was high (84% of landowners). Installed BMPs included waste management plans, septic systems, dairy lagoons, poultry composters, waste storage structures, tree planting, and soil testing. About 80% of the P present was in the ortho-phosphate form (ortho-P). Ortho-P concentrations during baseflow events prior to BMP installation exhibited a mean of 0.067 mg/L. The mean baseflow ortho-P decreased to 0.024 mg/L after BMP installation. During storm flow conditions, the mean ortho-P decreased by more than an order of magnitude from 0.41 mg/L to 0.035 mg/L in response to installation of the BMPs (Haraughty 1999). It is noteworthy that these BMPs were not targeted in a punitive fashion to one industry, but rather resulted from voluntary adoption of a variety of practices among members of the entire community that resided within the watershed. Haraughty (1999, page 11) noted that, in the process of preparing the Comprehensive Basin Management Plan for the Oklahoma portion of the IRW,:

> ***Although some of these groups have specific interests in production activities within the basin, there was a noticeable lack of finger pointing. Each group recognized that the problems and causes were many and that contributions from all areas must be addressed.***

23. *Plaintiffs' consultant, Dr. Olsen, lists on page 6-16 of his report for this case 22 substances which he claims are both hazardous and are contained in poultry waste. However, for most of these listed substances, Dr. Olsen provides no analyses to demonstrate that any harm has occurred to humans or the environment that can be associated with such substances.*

Neither does Dr. Olsen provide quantitative information to describe water quality standards for these substances or to document that water in the IRW exceeds such standards, or that many of these substances actually occur in water within the IRW, or that such occurrence of such substances in water in the IRW is attributable to land application of poultry litter. In essence, Dr. Olsen throws out a laundry list of hazardous substances, with no analyses to document the relevance of this list to water quality or effects in the IRW. This list is in conflict with statements by Plaintiffs' consultant, Dr. Fisher, (Fisher 2008, page 4) that:

> ***The contaminants of concern within the Illinois River Watershed are phosphorus and bacteria.***

Furthermore, other than P, these substances are not claimed by Plaintiffs' consultants to be associated with eutrophication of waters in the IRW

IV. REFERENCES CITED

Alexander, R. B. and R. A. Smith. 2006. Trends in the nutrient enrichment of U. S. rivers during the late 20th century and their relation to changes in probable stream trophic conditions. Limnol. Oceanogr. 51(1, part 2): 639-654.

Allan, J. D., D. L. Erickson, and J. Fay. 1997. The influence of catchment land use on stream integrity across multiple spatial scales. Freshwater Biology 37: 149-161.

Arkansas Audubon Society. 2008. Arkansas bird records database. Version 8.1. http://www.arbirds.org/aas_dbase.html. Accessed

Arkansas Department of Pollution Control and Ecology. 1995. Water quality survey and biological assessment of the effects of wastewater discharges from the city of Siloam Springs on Sager Creek. Arkansas Department of Pollution Control and Ecology and Oklahoma Water Resources Board.

Benke, A. C., G. E. Willeke, F. K. Parrish, and D. L. Stities. 1981. Effects of urbanization on stream ecosystems. Completion report, Project No. A-055-GA. Office of Water Research and Technology. U.S. Dept. of Interior.

Birch, P. B., R. S. Barnes, and D. E. Spyridakis. 1980. Recent sedimentation and its relationship with primary productivity in four western Washington lakes. Limnol. Oceanogr. 25(2): 240-247.

Brady, N. C. and R. R. Weil. 1999. The nature and properties of soils. Upper Saddle River, N.J.: Prentice Hall.

Brown, D. L. 2008. Report concerning the sampling program for the Oklahoma Poultry Litigation.

Butler, D. M., D. H. Franklin, N. Ranells, M. H. Poore, and J. T. Green. 2006. Ground cover impacts on sediment and phosphorus export from manured riparian pasture. J. Environ. Qual. 35: 2178-2185.

Caneday, L. 2008. Expert Report for Case No. 4:05-CV-00329-GKF-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants. 27 pp.

Churchill, J. 2008. Conestoga-Rovers and Associates (CRA) second report for the Illinois River Watershed, Oklahoma and Arkansas. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

Clark II, E. H., J. A. Havercamp, and W. Chapman. 1985. Eroding Soils: The Off-Farm Impacts. Washington, DC: The Conservation Foundation.

Clark, M. L. C., C. A. Eddy-Miller, and M. A. Mast. 1999. Environmental characteristics and water quality of hydrologic benchmark network stations in the West-Central United States. USGS. http:pubs.usgs.gov/circ/circ1173/circ1173c.html.

Clay, B. R. 2008. Expert Report for Case No. 4:05-CV-00329-GKF-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

Connolly, J. 2009. Expert Report for Case No. 4:05-CV-00329-GFK-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

Cooke, G. D. and E. B. Welch. 2008. Eutrophication of Tenkiller Reservoir, Oklahoma and Effects on Water Quality and Fisheries. Expert Report for Case No. 05-CU-329-GKF-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs Tyson Foods, Inc. et al., Defendants.

Cox, F. R. and S. E. Hendricks. 2000. Soil test phosphorus and clay content effects on runoff water quality. J. Environ. Qual. 29: 1582-1586.

Coyne, M. S., R. A. Gilfillen, R. W. Rhodes, and R. L. Blevins. 1995. Soil and fecal coliform trapping by grass filter strips during simulated rain. J. Soil Water Cons. 50(4): 405-408.

Coyne, M. S., R. A. Gilfillen, A. Villalba, Z. Zhang, R. W. Rhodes, L. Dunn, and R. L. Blevins. 1998. Fecal bacterial trapping by grass filter strips during simulated rain. J. Soil Water Cons. 53(2): 140-145.

Daniel, T. C., D. R. Edwards, and D. J. Nichols. 1995. Edge-of-Field Losses of Surface-Applied Animal Manure. In: Steele, K., ed. Animal Waste and the Land-Water Interface.

Daniels, M., T. Riley, M. Wilson, K. VanDevender, A. Baber, W. Austin, and H. Denniston. Undated. Arkansas Nutrient Management Guide. Prepared in cooperation with Arkansas Association of Conservation Districts, Arkansas Soil and Water Conservation Commission, Arkansas Department of Environmental Quality, and Natural Resources Conservation Service. Little Rock: University of Arkansas, Division of Agriculture.

Dauwalter, D. C., E. J. Pert, and W. E. Keith. 2003. An index of biotic integrity for fish assemblages in Ozark highland streams of Arkansas. Southeastern Naturalist 2(3): 447-468.

Dillon, P. J. and W. B. Kirchner. 1975. The effect of geology and land use on the export of phosphorus from watersheds. Water Research 9: 135-148.

Dunford, R. W. 2008. Declaration for Case No. 4:05-CV-00329-GFK-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

DuPont, H. L. 2008. Expert Report for Case No. 4:05-CV-00329-GKF-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

Edwards, D. R., I. Chaubey, T. D. Daniel, and P. A. Moore Jr. 1995. Modeling vegetative filter strip performance for runoff from plots receiving poultry litter. In: Heatwole, C., ed. Proceedings from the International Symposium on Water Quality Modeling. Orlando, FL; pp. 78-86.

Ekka, S. A., B. E. Haggard, M. D. Matlock, and I. Chaubey. 2006. Dissolved phosphorus concentrations and sediment interactions in effluent-dominated Ozark streams. Ecological Engineering 26: 375-391.

Engel, B. 2008. Poultry waste generation and land application in the Illinois River Watershed and phosphorus loads to the Illinois River Watershed streams and rivers and Lake Tenkiller. Expert Report of Dr. B. Engel for State of Oklahoma. State of Oklahoma v. Tyson Foods, et al.

Engineering Services Inc. 2004. Septic tank survey of Tontitown, Arkansas and Highfill, Arkansas for Osage Basin Watershed District. Springdale, Arkansas.

Fisher, B. 2008a. Volume II of the Videotaped Deposition in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiffs vs Tyson Foods, Inc., et al., Defendants Case No. 4:05-CV-00329-TCK-SAJ,

Fisher, J. B. 2008b. Expert Report for Case No. 4:05-CV-00329-GFK-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

Fisher, J. B. and D. Brown. 2007. SOP: 10-1. Standard Operating Procedure. Edge of Field Sampling. Revision 1. CDM. 8 pp.

Gburek, W. J. and A. N. Sharpley. 1998. Hydrologic controls on phosphorus loss from upland agricultural watersheds. J. Environ. Qual. 27: 267-277.

Gburek, W. J., A. N. Sharpley, and G. J. Folmar. 2000a. Critical areas of phosphorus export from agricultural watersheds. In: Sharpley, A. N., ed. Agriculture and Phosphorus Management. Boca Raton, FL: Lewis Publishers.

Gburek, W. J., A. N. Sharpley, L. Heathwaite, and G. J. Folmar. 2000b. Phosphorus management at the watershed scale: a modification of the phosphorus index. J. Environ. Qual. 29: 130-144.

Gibb, H. J. 2008. Expert Report for Case No. 4:05-CV-00329-GKF-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

Graham, J. L., J. R. Jones, S. B. Jones, J. A. Downing, and T. E. Clevenger. 2004. Environmental factors influencing microcystin distribution and concentration in the Midwestern United States. Water Research 38: 4395-4404.

Grip, W. M. 2008. Expert Report for Case No. 4:05-CV-00329-GKF-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

Grip, W. M. 2009. Statement of Opinions for Case No. 4:05-CV-00329-GFK-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

Haggard, B. E. and T. S. Soerens. 2006. Sediment phosphorus release at a small impoundment on the Illinois River, Arkansas and Oklahoma, USA. Ecological Engineering 28: 280-287.

Haggard, B. E., D. E. Storm, and E. H. Stanley. 2001. Effect of a point source input on stream nutrient retention. Journal of the American Water Resources Association 37(5): 1291-1299.

Haggard, B. E., J. R. Masoner, and C. J. Becker. 2003a. Percentile distributions of median nitrite plus nitrate as nitrogen, total nitrogen, and total phosphorus concentrations in Oklahoma streams, 1973-2001. U.S. Department of the Interior, U.S. Geological Survey. Water-Resources Investigations Report 03-4084.

Haggard, B. E., T. S. Soerens, W. R. Green, and R. P. Richards. 2003b. Using regression methods to estimate stream phosphorus loads at the Illinois River, Arkansas. Appl. Eng. Agri. 19(2): 187-194.

Haggard, B. E., S. A. Ekka, M. D. Matlock, and I. Chaubey. 2004. Phosphate equilibrium between stream sediments and water: potential effect of chemical amendments. Transactions of the American Society of Agricultural Engineers 47(4): 1113-1118.

Haggard, B. E., K. L. White, I. Chaubey, M. D. Matlock, W. R. Green, P. B. Delaune, and P. A. Moore Jr. 2003c. Phosphorus sources in an Ozark catchment, USA: Have we forgotten phosphorus from discrete sources. Proceedings Report, International Water Association Annual Meeting. Dublin, Ireland.

Haraughty, S. 1999. Comprehensive Basin Management Plan for the Illinois River Basin in Oklahoma. Water Quality Division, Oklahoma Conservation Commission. 150 pp.

Harmel, R. D., H. C. T., and R. Dutnell. 1999. Bank erosion and riparian vegetation influences: Upper Illinois River, Oklahoma. Transactions of the American Society of Agricultural Engineers 42(5): 1321-1329.

Harwood, V. J. 2008. Transcript of the testimony of Valerie J. Harwood, PhD. W.A. Drew Edmondson, et al. vs. Tyson Foods, Inc. et al.

Haygarth, P. M. and S. C. Jarvis. 1999. Transfer of phosphorus from agricultural soils. Advances in Agronomy 66: 195-249.

Heathwaite, L., P. Haygarth, and R. Dils. 2000. Pathways of phosphorus transport. In: Sharpley, A. N., ed. Agriculture and Phosphorus Management. Boca Raton, FL: Lewis Publishers.

Hobbie, J. E. and G. E. Likens. 1973. Output of phosphorus, dissolved organic carbon, and fine particulate carbon from Hubbard Brook watersheds. Limnol. Oceanogr. 18: 734-742.

Horne, A. 2009. Expert Report for Case No. 4:05-CV-00329-GFK-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

House, W. A., F. H. Denison, and P. D. Armitage. 1995. Comparison of the uptake of inorganic phosphorus to a suspended and stream bed-sediment. Water Research 29(3): 767-779.

Indian Nations Council of Governments. 2008. Bacteria total maximum daily loads for Arkansas River Segments OK120420010010_00, OK120410010080_00 & Haikey Creek Segment OK120410010210_00. Tulsa, OK: Oklahoma Department of Environmental Quality.

Jarman, R. L. 2008. Expert Report for Case No. 4:05-CV-00329-GKF-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

Johnson, G. V. 2008. Expert Report for Case No. 4:05-CV-00329-GKF-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants. 23 pp.

Johnson, L. B., C. Richards, G. E. Host, and J. W. Arthur. 1997. Landscape influences on water chemistry in midwestern stream ecosystems. Freshwater Biology 37: 193-208.

Jones, C. and C. C. Clark. 1987. Impact of watershed urbanization on stream insect communities. Wat. Resour. Bull. 23(6): 1047-1055.

Jones, J. R., M. F. Knowlton, D. V. Obrecht, and E. A. Cook. 2004. Importance of landscape variables and morphology on nutrients in Missouri reservoirs. Can. J. Fish. Aquat. Sci. 61: 1503-1512.

Klein, R. D. 1979. Urbanization and stream quality impairment. Wat. Resour. Bull. 15(4): 948-963.

Kleinman, P. J. A., A. N. Sharpley, B. G. Moyer, and G. F. Elwinger. 2002. Effect of mineral and manure phosphorus sources on runoff phosphorus. J. Environ. Qual. 31: 2026-2033.

Kleinman, P. J. A., R. B. Bryant, W. S. Reid, A. N. Sharpley, and D. Pimentel. 2000. Using soil phosphorus behavior to identify environmental thresholds. Soil Science 165(12): 943-950.

Kuehl, R. O. 2000. Design of Experiments: Statistical Principles of Research Design and Analysis. 2nd ed. Duxbury Press.

Larson, S. P. 2008. Expert Report for Case No. 4;05-CV-00329-GKF-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants.

Lenat, D. R. and J. K. Crawford. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. Hydrobiologia 294: 185-199.

Leytem, A. B., J. T. Sims, and F. J. Coale. 2003. On-farm evaluation of a phosphorus site index for Delaware. J. Soil Water Cons. 58: 89-97.

Litke, D. W. 1999. Review of phosphorus control measures in the United States and their effects on water quality. Denver, Colorado: USGS National Water-Quality Assessment Program. Water-Resources Investigations Report 99-4007.

Madden, M. P. 2008. Videotaped Deposition in the U.S. District Court for the Northern District of Oklahoma, September, 2008, for Case No. 05-CV-00329-GKF SAJ. State of Oklahoma, et al. vs. Tyson Foods, et al.

Myoda, S. 2008. Expert Report for Case No. 4:05-CV-00329-GKF-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants. 36 pp.

Nelson, M. A. 2003. Illinois River 2002 Pollutant Loads: at Arkansas Highway 59 Bridge. Fayetteville, Arkansas: Arkansas Soil and Water Conservation Commission and the Arkansas-Oklahoma Arkansas River Compact Commission.

Novotny, V. 1980. Delivery of suspended sediment and pollutants from nonpoint sources during overland flow. Wat. Resour. Bull. 16(6): 1057-1065.

Novotny, V. 1995. Nonpoint Pollution and Urban Stormwater Management. Lancaster, PA: Technomic Publishing Company, Inc.

Novotny, V. and G. Chesters. 1981. Handbook of nonpoint pollution: sources and management. New York: Van Nostrand Reinhold.

Novotny, V. and H. Olem. 1994. Water Quality. Prevention, Identification and Management of Diffuse Pollution. New York: Van Nostrand-Reinhold.

Oklahoma Department of Environmental Quality. 1997. Illinois River Project: Potential Impact of Waste Water.

Oklahoma Department of Environmental Quality. 2004. The State of Oklahoma 2004 Water Quality Assessment Integrated Report. Prepared Pursuant to Section 303(d) and Section 305(b) of the Clean Water Act.

Oklahoma Scenic Rivers Commission, Oklahoma State University, and National Park Service. 1999. The Illinois River Management Plan.

Oklahoma Water Resources Board. 2007. 2007 Report of the Oklahoma Beneficial Use Monitoring Program: Streams Report. State of Oklahoma Water Resources Board (OWRB).

Osborne, L. L. and M. J. Wiley. 1988. Empirical relationships between land use/cover and stream water quality in an agricultural watershed. J. Environ. Manage. 26: 9-27.

Parker, D. G., R. Williams, and E. Teague. 1996. Illinois River Water Quality Automatic Sampler Installation. Fayetteville, Arkansas: Arkansas Water Resources Center.

Parsons. 2006a. Bacteria total maximum daily loads for North Canadian River and Shell Creek, in the North Canadian River Basin, Oklahoma (OKWBID 52053). Oklahoma Department of Environmental Quality.

Parsons. 2006b. Bacteria total maximum daily loads for Canadian River, Oklahoma (OKWBID 52062). Oklahoma Department of Environmental Quality.

Parsons. 2007a. Bacteria total maximum daily loads for the Washita River, Oklahoma (OK310800, OK310810, OK310820, OK310830, OK310840). Oklahoma Department of Environmental Quality.

Parsons. 2007b. Bacteria total maximum daily loads for OK410400, OK410600, OK410700 in the Boggy Creek Area, Oklahoma. Oklahoma Department of Environmental Quality.

Parsons. 2007c. Bacteria total maximum daily loads for the Lower Red River Area, Oklahoma (OK311100, OK311200, OK311210, OK311300, OK311310. Oklahoma Department of Environmental Quality.

Parsons. 2007d. Bacteria total maximum daily loads for OK410210, OK410300, OK410310 in the Little River Area, Oklahoma. Oklahoma Department of Environmental Quality.

Parsons. 2008a. Bacteria total maximum daily loads for OK220100, OK220200, OK220600 in the San Bois Creek Area, Oklahoma. Oklahoma Department of Environmental Quality.

Parsons. 2008b. Bacteria total maximum daily loads for the Upper Red River Area, Oklahoma (OK311500, OK311510, OK311600, OK311800). Oklahoma Department of Environmental Quality.

Parsons. 2008c. Bacteria total maximum daily loads for the Neosho River Basin, Oklahoma (OK121600). Oklahoma Department of Environmental Quality.

Parsons. 2008d. Draft: Bacterial total maximum daily loads for the Canadian River Area, Oklahoma (OK520600, OK520610, OK520800). Oklahoma Department of Environmental Quality.

Perkins, B. D., K. Lohman, E. V. Niuewenhuyse, and J. R. Jones. 1998. An examination of land cover and stream water quality among physiographic provinces of Missouri, U.S.A. Verh. Internat. Verein. Limnology 26: 940-947.

Pickup, B. E., W. J. Andrews, B. E. Haggard, and W. R. Green. 2003. Phosphorus concentrations, loads, and yields in the Illinois River Basin, Arkansas and Oklahoma, 1997-2001. U.S. Department of the Interior U.S. Geological Survey. Water-Resources Investigations Report 03-4168. 45 pp.

Pionke, H. B., W. J. Gburek, A. N. Sharpley, and J. A. Zollweg. 1997. Hydrological and chemical controls on phosphorus loss from catchments. In: Tunney, H., O. T. Carton, P. C. Brookes, and A. E. Johnston, eds. Phosphorus Loss from Soil to Water. Oxon, United Kingdom and New York, NY: CAB International; pp. 225-242.

Pitois, S., M. H. Jackson, and B. J. B. Wood. 2001. Sources of the eutrophication problems associated with toxic algae: an overview. Journal of Environmental Health 64(5): 25-32.

Popova, Y. A., V. G. Keyworth, B. E. Haggard, D. E. Storm, R. A. Lynch, and M. E. Payton. 2006. Stream nutrient limitation and sediment interactions in the Eucha – Spavinaw Basin, USA. J. Soil Water Cons. 61: 105-115.

Radcliffe, D. E. and N. Nelson. 2005. Predicting phosphorus losses. Southern Extension and Research Activity – Information Exchange Group 17 (SERA-17) Position Paper.

Reavie, E. D. and J. P. Smol. 2001. Diatom-environmental relationships in 64 alkaline southeastern Ontario (Canada) lakes: a diatom-based model for water quality reconstructions. Journal of Paleolimnology 25: 25-42.

Riseng, C. M., M. J. Wiley, and R. J. Stevenson. 2004. Hydrologic disturbance and nutrient effects on benthic community structure in midwestern U.S. streams: a covariance structure analysis. Journal of the North American Benthological Society 23(2): 309-326.

Ritter, W. F. 2001. Nonpoint source pollution and livestock manure management. In: Ritter, W. F., and A. Shirmohammadi, eds. Agricultural nonpoint source pollution: watershed management and hydrology. Boca Raton, FL: Lewis Publishers.

Ritter, W. F. and A. Shirmohammadi. 2001. Agricultural Nonpoint Source Pollution: Watershed Management and Hydrology. Boca Raton, FL: Lewis Publ.

Sauer, T. J., T. C. Daniel, D. J. Nichols, C. P. West, P. A. Moore Jr., and G. L. Wheeler. 2000. Runoff water quality from poultry litter-treated pasture and forest sites. J. Environ. Qual. 29: 515-521.

Schelske, C. L. and D. A. Hodell. 1995. Using carbon isotopes of bulk sedimentary organic matter to reconstruct the history of nutrient loading and eutrophication in Lake Erie. Limnol. Oceanogr. 40(5): 918-929.

Schoumans, O. F. and A. Breeuwsma. 1997. The relation between accumulation and leaching of phosphorus: laboratory, field and modelling results. In: Tunney, H., O. T. Carton, P. C. Brookes, and A. E. Johnston, eds. Phosphorus loss from soil to water. Cambridge, UK: CAB International Press; pp. 361-363.

Sharpley, A. and H. Tunney. 2000. Phosphorus research strategies to meet agricultural and environmental challenges of the 21st century. J. Environ. Qual. 29(1): 176-181.

Sharpley, A. N., T. C. Daniel, and D. R. Edwards. 1993. Phosphorus movement in the landscape. Journal of Production Agriculture 6(4): 492-500.

Sharpley, A. N., R. W. McDowell, and P. J. A. Kleinman. 2001. Phosphorus loss from land to water: integrating agricultural and environmental management. Plant and Soil 237: 287-307.

Sharpley, A. N., T. Daniel, T. Sims, J. Lemunyon, R. Stevens, and R. Parry. 2003a. Agricultural phosphorus and eutrophication. USDA Agricultural Research Service. ARS-149.

Sharpley, A. N., J. L. Weld, D. B. Beegle, P. J. A. Kleinman, W. J. Gburek, P. A. Moore Jr., and G. Mullins. 2003b. Development of phosphorus indices for nutrient management planning strategies in the United States. J. Soil Water Cons. 58: 137-152.

Sheffield, R. E., S. Mostaghimi, D. H. Waughan, C. J. E. R., and V. G. Allen. 1997. Off-stream water sources for grazing cattle as a stream bank stabilization and water quality BMP. Transactions of the ASAE 40(3): 595-604.

Smith, K. A., D. R. Jackson, and P. J. A. Withers. 2001. Nutrient losses by surface run-off following the application of organic manures to arable land. 2. Phosphorus. Environ. Poll. 112: 53-60.

Smith, M. 2008. Illinois River Watershed Phosphorus Mass Balance Study. Deposition Exhibit 67. Alexander Consulting, Inc. ACI Project ES-239.

Søndergaard, M., P. Kristensen, and E. Jeppesen. 1992. Phosphorus release from resuspended sediment in the shallow and wind-exposed Lake Arresø, Denmark. Hydrobiologia 228: 91-99.

Stevenson, R. J. 2008. Nutrient pollution of streams in the Illinois River Watershed, Oklahoma: effects on water quality, aesthetics, and biodiversity. Expert Report of Dr. R. Jan Stevenson for State of Oklahoma. State of Oklahoma v. Tyson Foods, et al.

Stoermer, E. F., J. A. Wolin, and C. L. Schelske. 1993. Paleolimnological comparison of the Laurentian Great Lakes basin on diatoms. Limnol. Oceanogr. 38(6): 1311-1316.

Sullivan, T. J., J. M. Bischoff, and K. B. Vaché. 1998a. Results of storm sampling in the Tillamook Bay Watershed. Report to Tillamook Bay National Estuary Project. Corvallis, OR: E&S Environmental Chemistry, Inc.

Sullivan, T. J., J. M. Bischoff, K. B. Vaché, M. Wustenberg, and J. Moore. 1998b. Water quality monitoring in the Tillamook watershed: results of a one-year periodic monitoring and storm sampling program. Report to the Tillamook Bay National Estuary Project. Corvallis, OR: E&S Environmental Chemistry, Inc.

Sullivan, T. J., M. Wustenberg, J. A. Moore, K. U. Snyder, E. H. Gilbert, D. Moore, and E. Mallery. 2004. Riparian plantings and fencing improve water quality in Tillamook River Watershed (Oregon). Ecological Restoration 22(2): 138-140.

Svendsen, L., B. Kronvang, P. Kristensen, and P. Graesbol. 1995. Dynamics of phosphorus compounds in a lowland river system: importance of retention and nonpoint sources. Hydrological Processes 9: 119-142.

Teaf, C. M. 2008. Expert Report for Case No. 4:05-CV-00329-GKF-SAJ in the U.S. District Court for the Northern District of Oklahoma. State of Oklahoma, Plaintiff vs. Tyson Foods, Inc. et al., Defendants. 114 pp.

Turner, B. L. and A. B. Leytem. 2004. Phosphorus compounds in sequential extracts of animal manures: Chemical Speciation and a novel fractionation procedure. Environmental Science and Technology 38: 6101-6108.

U.S. Environmental Protection Agency. 1983. Results of the Nationwide Urban Runoff Program: Executive Summary. Washington, D.C.: Water Planning Division: U. S. Environmental Protection Agency.

U.S. Environmental Protection Agency. 2002. National Water Quality Inventory: 2000 Report. Washington, DC: U.S. Environmental Protection Agency Office of Water. EPA-841-R-02-001.

U.S. Environmental Protection Agency. 2003. Federal Register. Part II. Environmental Protection Agency. 40 CFR Parts 9, 122, 123, and 412. National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitation Guidelines and Standards for Concentrated Animal Feeding Operations (CAFOs); Final Rule. http://nmplanner.missouri.edu/regulations/2003_final_cafo_rule_fedrgstr.pdf.

U.S. Environmental Protection Agency. 2006. Wadeable streams assessment: a collaborative survey of the nation's streams. Washington, DC: U. S. Environmental Protection Agency, Office of Water.

Wade, T. J., N. Pai, J. N. S. Eisenberg, and J. M. Colford Jr. 2003. Do U.S. Environmental Protection Agency water quality guidelines for recreational waters prevent gastrointestinal illness? A systematic review and meta-analysis. Environmental Health Perspectives 111(8): 1102-1109.

Wang, L., J. Lyons, P. Kanehl, and R. Gatti. 1997. Influences of watershed land use on habitat quality and biotic integrity in Wisconsin Streams. Fisheries 22(6): 7-12.

Watershed Conservation Resource Center. 2005. Geospatial Inventory and Assessment of Sediment from Unpaved Roads in the North Big Creek, Chandler Creek, Lick Branch Watersheds. Sub-watersheds of the Strawberry River Watershed, Arkansas.

Weld, J. L., A. N. Sharpley, D. B. Beegle, and W. J. Gburek. 2001. Identifying critical sources of phosphorus export from agricultural watersheds. Nutrient Cycling in Agroecosystems 59: 29-38.

Young, R. A., T. Huntrods, and W. Anderson. 1980. Effectiveness of vegetated strips in controlling pollution from feedlot runoff. J. Environ. Qual. 9: 483-487.

V. ADDENDUM

I hereby adopt as part of this report my previous testimony in the Preliminary Injunction hearing and my associated report.

VI. APPENDICES

Appendix A. Specific Responses to Selected Plaintiffs' Consultants

Stevenson

On pages 17 and 18, and in the Summary and Opinions (Section 6) Dr. Stevenson (2008) states that in a comparison with streams in other regions, streams in the IRW have higher nutrient concentrations than streams in those regions. But Stevenson does not present any data to back up that statement. The data sources are not identified and no comparative data are presented.

Dr. Stevenson states that the application of poultry waste to pasture lands is "a substantial source of P in streams of the IRW" (page 1) and he cites the Engel Expert Report as the basis of that assertion. There is nothing in the Stevenson report that connects stream or reservoir P concentration (or any other water quality parameter) to the application of poultry litter or to any other agricultural practice. Dr. Stevenson merely illustrates, by virtue of correlations that are frequently weak and statistically insignificant, that P concentration in some cases tends to be higher at locations that include larger numbers of poultry houses within their watersheds. Partial correlation r^2 values suggested that percent urban land use explained more of the variation in the model than poultry house density (Chadwick 2009). Most importantly, Dr. Stevenson ignores the obvious cross correlation between poultry house density and the density of other land use activities that are known contributors to stream P pollution, in particular the densities of septic systems, human inhabitants, cattle, and roads and other sources of erosion (which are typically enriched in P). Therefore, the summary opinion stated on page 46 that his studies "show that poultry house operations are related to the nutrient pollution…" in the IRW is without merit.

For Summer 2006, the stream TP concentration was significantly correlated with urban land use ($P<0.001$), but not to poultry house density when using the 0.05 benchmark for attainment of statistical significance ($p< 0.05$). He stated that effects (of poultry house density) were masked statistically by high TP in waters downstream from urban land use. When he restricted the analysis to a subset of the data in which urban land use was less than 10 percent of the watershed, poultry house density only explained 22 percent of the variation in TP concentration (Stevenson 2008, page 19). Similarly, his multimetric indicator of nutrient conditions was significantly correlated with percent urban land ($P<0.001$) in a multiple regression model, but was not significantly related to poultry house density. When that dataset was constrained to watersheds having low urban land use and a gradient of poultry house density, then the poultry house density variable explained a mere 16% of the variation in nutrient conditions. Multiple regression models for the spring and summer 2007 data showed statistically significant relationships with both percent urban land use and poultry house density. Because poultry houses are primarily distributed across the non-urban landscape in the IRW, this regression merely indicates that TP is spatially correlated with both urban land use (represented as percent urban land cover) and agricultural land use (represented as poultry house density). What Dr. Stevenson leaves out of his discussion is the fact that along with the poultry houses, agricultural land use in the IRW also includes rural residential housing, septic systems, cattle and other livestock, roads, and other sources of nutrient NPS pollution. These land uses are correlated with each other.

Dr. Stevenson's regression analyses for other variables are mainly an extension of his P analyses. If, as he claims, algal biomass is strongly influenced by stream P concentrations, then one would also expect (as he found) significant relationships with variables that reflect algal biomass. He found no significant relationship at $P< 0.05$ between dissolved oxygen (DO) and poultry house density in summer 2006 or Spring 2007. He claimed (page 30) that average pH increased with increasing benthic algal biomass, filamentous green algae (FGA) cover, TP concentration, urban land use, and "probably poultry house density" . Dr. Stevenson has no basis whatsoever for this latter claim. Each of the first four variables in this list were significant at p< 0.05 or better; thus, these relationships are indeed significant. But the reported p value for the relationship with poultry house density was 0.166. This is not remotely statistically significant using commonly accepted scientific criteria.

For example, Plaintiffs' own consultant, Dr. Olsen (page 6-30), defined a statistically significant correlation, in accordance with commonly-accepted practice, as:

> ***"one in which p<0.05 (95% significant level)."***

This p value is commonly selected as the benchmark of statistical significance in environmental studies. A similar conclusion was reached by Chadwick (2009).

The significance level of a test statistic is the probability of exceeding the value of the test statistic under the null hypothesis condition (Kuehl 2000). As explained by Kuehl (2000, page 58):

> ***The magnitude of the p-value is used by many investigators to decide the statistical significance of the F test in the analysis of variance. The value is frequently reported in a discussion of results. For example, the F test for the present example may be reported as "significant at the P< .0001 level of significance." <u>If the probability value is less than the traditional significance levels of .01 or .05 the null hypothesis will be rejected</u> because the observed F_0 statistic is in the critical region (***Underline provided for emphasis***).***

Plaintiff's consultant, Dr. Harwood agreed with the guidance given by Kuehl (2000). Dr. Harwood stated in her July 18, 2008 deposition (page 154):

> ***If P is less than 0.05, then by most general statistical cutoffs, then that's a statistically significant correlation.***

There are other cases in the Stevenson (2008) report where the data are distorted. For example, on page 40 he states "*In addition to the number of fish species*, poultry house density and nutrient enrichment were related to other indicators, which help characterize changes in fish community composition in streams". (Italics added for emphasis.) But in the previous paragraph, he had just revealed that the number of fish taxa (that is number of species) was "poorly related to poultry house density (p=0.140) and not related well to TP (p<0.278), DO (p<0.628)…" First of all, these p values do not indicate "poorly related" or "not related well". They are simply not statistically significant at the commonly accepted 0.05 p value. What he should have said was simply that the number of fish species was not related to poultry house density. Similarly, in Table 4.1, Dr. Stevenson provides p values for the observed statistical relationships between TP and poultry house density on the one hand and 13 variables that he devised to reflect various aspects of the fish community in the IRW. None of the 13 variables were significantly (p<0.05) correlated with TP. Only 2 of the 13 variables, the proportion of what he termed "sensitive individuals"(which was never defined) and the number of what he termed "lithophillic taxa" (also not defined), were statistically (p<0.05) correlated with poultry house density. Again, the poultry house density variable was itself correlated with other land use activities known to contribute NPS nutrient enrichment. It is not clear what these correlations mean with respect to the quality or health of the fish community, but it is clear that Dr. Stevenson does not offer data that support his conclusion on page 47 that “The diversity of fish decreased and their species composition changed in IRW streams in relation with nutrient enrichment and poultry house activities”.

Dr. Stevenson correctly states on page 21 that many studies relate the percent of watersheds used by humans for urban or agricultural activities to nutrient concentrations in streams, and he cites in support of this contention publications by Johnson et al. (1997), Allan et al. (1997), and Dauwalter et al. (2003). Dr. Stevenson does not demonstrate that these relationships are dependent on the presence of poultry operations.

<u>Engel</u>

The Smith/Engel P mass balance study assigns small values (dairy cattle, 5.2%; beef cattle, 1.7%) to P contributions from cattle. This is because cattle feed on grass growing inside the watershed and relatively little food is imported from outside the watershed to feed these animals. Using the logic of this mass balance study, it would be possible for cattle in the IRW to eat grass that grows in areas that leach absolutely no P to stream waters, and then walk into the stream and defecate into the water. Under this scenario, cattle could transport an unquantifiable amount of P from soil and grass to stream water, thereby constituting a potentially important source of P to streams and yet not register in the mass balance as having any role in water pollution within the watershed. Soils within the IRW contain a large pool of P within the soil. Some of that P is derived naturally from weathering; some has been added in the form of poultry litter or other fertilizer sources. This soil P pool does not contribute to stream P content unless that P is transported from the soil to the stream. Having P present in the soil is not sufficient to cause higher concentration of P in stream water. P is always present in soils, whether they be forest soils, urban soils, or agricultural soils. The mere presence of P in the soil is not sufficient to cause a water pollution problem. Thus, it is not the amount of P transported into the watershed that causes stream water to increase in P concentration; it is the transport of P from soils to streams that causes this to occur. This mass balance study tells us nothing about the most important issue, P transport to streams.

<u>Fisher</u>

Dr. Fisher (2008b), in his first conclusion, described on pages 8 and 9 of his report, claims that certain constituents:,

> ***would not be present as contaminants in soils, edge-of-field runoff, surface water in streams and in Lake Tenkiller, groundwater, stream sediments and lake sediments except for the actions and practices of Defendants.***

There is no basis for this statement. Most of these constituents (for example, P, sodium, potassium, calcium, copper, zinc, and arsenic) are essential nutrients for plant and animal life. All are widely distributed throughout the environment. Such elements are found in various environmental compartments with and without poultry litter application to pasture lands. Furthermore, I don’t recall other examples of people claiming that soil or water was polluted with calcium or potassium. Quite commonly, however, I have found environmental conditions to be deficient of calcium. Calcium can be added to streams, lakes, forest soils, grasslands, and lawns to alleviate calcium deficiency and/or acidity.

Most of Dr. Fisher's (2008b) conclusions do not relate ***directly*** to the possibility that poultry litter application to pasture lands in the IRW is a cause of water pollution in the watershed. However, Dr. Fisher's conclusions 4 and 5 do focus on the possibility of water pollution from poultry litter application, but Dr. Fisher offers no information, data, or analyses to support these two conclusions. He merely reiterates conclusions of other State's consultants. For example, in Section 4 of his report, Dr. Fisher states that

> ***poultry are the primary contributors to the phosphorus pollution of soils, surface waters, ground waters, and sediments within the Illinois River Watershed.***

In this section of his report, Dr. Fisher refers primarily to the report prepared by Dr. Engel for this case, and secondarily to the report prepared by Dr. Olsen for this case. In fact, Dr. Fisher does not provide any new information or new analyses of his own regarding his conclusion 4.

In Section 5 of his report, Dr. Fisher claims that

> ***Poultry are highly significant contributors to bacterial pollution of surface and groundwater within the Illinois River Watershed.***

Again, Dr. Fisher relies upon other of the Plaintiffs' consultants for this conclusion. He cites the DNA work of Dr. Harwood, the PCA of Dr. Olsen, and the report of Dr. Teaf (2008) as documentation for this conclusion. Dr. Fisher offers no additional analyses or insight of his own in this section of his report regarding the extent to which poultry may or may not contribute to bacteria contributions to streams in the IRW. Dr. Fisher's conclusions 6 through 16 focus on aspects of the poultry industry and poultry manure production, but really provide no information regarding the possibility or likelihood that the spreading of poultry litter on pasture lands contributes to stream or lake pollution in the IRW.

Dr. Fisher's main conclusion that actually attempts to link poultry litter application to contamination of stream water in the IRW is his conclusion 18, which claims that the chemical composition of poultry waste is distinctly different from the chemical composition of cattle waste and waste water treatment plant effluent. He uses this conclusion to support his assertions in conclusions 22 through 25, which claim that soils, edge-of-field runoff, ground water, and stream sediments are contaminated by poultry waste. Dr. Fisher's Figures 16, 17, 19, 20, 22, and 24 are offered in support of this conclusion. But these figures really only suggest that when P concentrations are high, the concentrations of various metals also tend in general to be high. This does not tell you what the source or sources of the P or the metals might be. Each constituent has a variety of sources of varying strength within the watershed and each constituent moves through the environment according to its own particular physical and chemical properties. (For more discussion, see Connolly 2009). In fact, Dr. Fisher acknowledged in his September 2, 2008 deposition, page 520, that P and the various metals found in poultry litter:

> ***are not conservative. They have differing interactions with environmental media.***

Therefore, his analyses of ratios of these constituents in different media do not indicate sources. For example, the following exchange took place during Dr. Fisher's deposition (May, 2008; page 521-522):

Q…Figure 16…Based on the plots, the regression lines that you've drawn for zinc, copper and arsenic as compared to phosphorus for these litter applied soil locations, isn't it true that there is no established relationship between phosphorus and these other chemicals, arsenic, copper and zinc, other than the simple fact that when phosphorus goes higher, the other chemicals go higher?

A. Okay. well, the graph shows that as phosphorus increases on these litter applied locations, that the concern – that the phos – well, the concentration of zinc, copper and arsenic increase, tend to increase.

Q. And that's all you can conclude from Figure 16; correct?

A. Well, since the only significant substantial source of phosphorus to these fields to my knowledge is poultry waste, then these materials are derived from poultry waste because it has substantial levels of phosphorus.

Again, it is Dr. Fisher's **assumption** that poultry litter is the dominant source that appears to be driving his interpretation of his data.

Dr. Fisher jumps, without basis, from the patterns shown in these graphs to his conclusion that concentrations of any of these parameters are derived from poultry waste. Similarly, on page 60, Dr. Fisher (2008b) states

As total P increases in Tenkiller sediments, total Cu, total Zn and total As also increase. This is consistent with these materials having the same concentrated source (i.e., poultry waste).

Dr. Fisher could have, but did not, go on to say that this pattern is also consistent with these materials having the same source (i.e., septic discharge, waste water plant effluent, cattle excrement, erosion, or urban runoff). He also could have said that this is consistent with these materials having different sources (i.e., some combination of the above NPS sources). The observed increases in the concentrations of P and various metals in Lake Tenkiller sediments could simply be due to the general increase in many or all sources of water pollution in this watershed during the latter half of the 20th Century. These data tell you little or nothing about the relative contribution of the various NPS sources.

In his conclusion 21, Dr. Fisher (2008b) states that

constituents of land disposed poultry waste run off fields… and are poorly attenuated.

He goes on to say that

if sufficient rainfall occurs in a short enough period of time, runoff is produced (i.e., not all of the water can be taken up by the soil and it runs off the field).

This last statement is of critical importance. As Dr. Fisher correctly states, runoff is produced when it rains hard enough that not all water can be taken up by the soil. What Dr. Fisher fails to state, however, is that it seldom rains with an intensity and duration sufficient to generate overland flow in most settings. As a consequence, there are certain limited portions of a given pasture that generate much of the overland flow during typical rainstorms. These are called the hydrologically active areas. They are also the portions of the pastures to which land owners are not allowed to apply poultry waste according to current regulations.

Dr. Fisher concluded that the population of poultry in the IRW has increased since at least 1950, that the amount of waste that they generate has increased, that there is a substantial amount of waste produced, that the waste is disposed near to where it is generated, and that it is mostly disposed of within the IRW. There is nothing about these conclusions that is unique to poultry. Exactly the same things can be said about people, cattle, and swine. Impacts of all sorts have increased in the IRW because the numbers of people, and their animals, have increased. Dr. Fisher's arguments that these increases in population numbers, and any associated effects, mainly concern poultry are without merit.

Dr. Fisher (2008b) goes on to suggest on page 62 that nutrients contained in beef cattle manure should be ignored in nutrient source estimates since a large proportion of these nutrients are obtained by the cattle from the forage and are recycled back to pastures. He ignores the fact that cattle also cycle (as opposed to recycle) nutrients from pasture and deposit them directly into the stream or to riparian areas adjacent to the stream from which they can be readily transported to the stream. There is no justification for removing cattle from the calculations based on the observation that they tend to consume forage grown within the watershed. Cattle are an effective agent of water pollution, in part, because they transport nutrients from forage into the stream or into a position from which they can be more readily moved into the stream when it rains. Construction of a watershed budget that ignores this fact is not pertinent to the questions at hand for determining the relative magnitude of potential NPS sources.

<u>Olsen</u>

Dr. Olsen's (2008) report is divided into an Introduction, four sections that present the methods and results of his field sampling program, and finally one section (Section 6) that evaluates sources of contamination in the IRW. My comments mainly pertain to Section 6. Dr. Olsen concludes that

> ***The chemical and bacterial contaminants of poultry waste are found in all the environmental fate and transport components throughout the IRW…***

He includes runoff water from fields, surface water, ground water, and springs in this characterization. But Dr. Olsen fails to state that the major constituent that he focuses on (P) is an important component of every potential source of both point and nonpoint source pollution in the IRW. Although P is found in poultry litter, it is also found in erosion (from stream banks, roads, heavily grazed areas, construction areas, parking lots, etc.), human waste (from waste water treatment plant outflows, septic system drainage, broken sewer lines, waste water spills and leaks, etc.), waste from other livestock (cattle, swine and horses), waste from wildlife, and runoff from urban and rural residential areas (for example, from pet waste and fertilizers). It is one of the most important nutrients for supporting virtually all forms of plant and animal life. Thus, the mere fact that P is found in various environmental compartments (e.g., edge-of-field, stream, lake, etc) of the IRW tells you nothing about the sources of that P or the relative magnitude of those sources. P is also expected to be found in these various environmental compartments in the absence of NPS pollution.

Dr. Olsen goes on to state that:

> ***the overall water quality characteristics of the surface waters in the IRW have been substantially changed when compared to surface water quality in reference locations***

This is an important conclusion. It is necessary, however, to clarify what Dr. Olsen means by "reference locations". This term is commonly used to indicate watersheds within areas of geographical similarity that have little or no quantifiable human impacts. Thus, a watershed that has been impacted by various point and/or nonpoint sources of water pollution might be compared with one or more reasonably pristine forested or native prairie reference watersheds that have not experienced the same various human perturbations that contribute stream pollution (e.g., urbanization, agriculture, grazing, logging, etc.). But comparison of the IRW with such reference watersheds does not have any relevance to the scientific questions at hand in this case that concern the relative magnitude of the various potential sources of P and other constituents to stream water. The IRW contains, in addition to a vibrant poultry industry, about 300,000 people, 200,000 cattle, 160,000 swine, multiple urban areas, substantial amounts of new construction, paved and unpaved roads, and widespread rural residential housing. The focus of my analyses in this case does not include an effort to determine the consequence of removing all sources of point and nonpoint pollution from the IRW. Rather, this case seems to me to be focused by the Plaintiffs' consultants on the effects, if any, of one potential source (poultry litter application) of NPS contributions to surface waters. Thus, an appropriate reference point of comparison for this case would be a watershed that is generally similar to the IRW with respect to the various land uses that can be sources of point and nonpoint pollution (i.e., urban development, cattle grazing, etc.), but that does not have an extensive poultry industry.

It appears that Dr. Olsen believes that appropriate reference watersheds in this case would be ones that receive no point or nonpoint inputs of water pollutants. This interpretation is incorrect.

Dr. Olsen (2008) concludes on page 6-9 that high concentrations of various contaminants, including P, in poultry waste should result in observable concentrations in the environmental compartments of the IRW (waters and sediment). This is not true. His conclusion totally ignores all aspects of pollutant transport and the fact that concentrations are diluted when more water is added to a stream. The concentration of a particular constituent at a particular location that does indeed move through the watershed changes from barn to field surface, to soil, to small stream, to river, to lake. Concentrations are always changing as more water is added or subtracted, additional pollutant sources are added, materials settle to the bottom of the stream or lake, nutrients are used by algae and plants, chemical transformations occur, etc., etc. The notion that the observed concentration of P in poultry litter tells you anything at all about the source of P to the Illinois River or to Lake Tenkiller is completely without merit.

Dr. Olsen's (2008) Pathway Sampling Approach, described in Section 6.5 of his report (pages 6-17 to 6-19), did not accomplish what was intended. His stated purpose was to:

> ***document, if possible, the fate and transport of poultry associated contamination from its origin (land disposal of poultry waste) through each environmental transport step to the ultimate deposition in the sediments and water of Lake Tenkiller.***

There were many problems with Dr. Olsen's analyses which prevented him from meeting that objective. One of the most important shortcoming of his analysis is that he did not account for all of the other sources that contribute exactly the same constituents as are found in poultry litter.

His soil sites receive waste from cattle, other livestock, and wildlife. His edge-of-field sites receive waste from the same sources as the soil sites plus erosion sources from roads and construction activities, runoff from housing developments and rural residences (i.e., fertilizers, septic systems, pet waste, hobby farm livestock, erosion). His stream and reservoir sites receive pollutants of all sorts from every point and nonpoint source of pollution in the watershed. These myriad sources provide the same pollutants to the Illinois River that Dr. Olsen claims are contributed from poultry litter land application. He offers no scientifically-defensible evidence supporting his claim that these pollutants found in the streams and in the reservoir are derived from poultry litter.

An additional major problem with Dr. Olsen's approach is that he offers no connection between the presence of the various constituents of land applied poultry waste, for example P, on pasture land and the presence of those same constituents in stream water. He claims that his edge-of-field samples represent that connection. But, his edge-of-field samples could contain contaminants derived from a wide range of sources; he ***assumes*** that they were derived from litter amended fields, and he ***ignores*** the obvious alternative sources that were present at many or all edge-of-field sampling locations. Dr. Olsen ***assumes*** that his edge-of-field water represents water movement from field to stream. But he did not collect any data that demonstrate such water or P movement.

Appendix B. Resume of Timothy J. Sullivan

TIMOTHY J. SULLIVAN

EDUCATION

Ph.D. Biological Sciences/Environmental Chemistry, Oregon State University - 1983
M.A. Biological Sciences, Western State College of Colorado - 1977
B.A. History, Stonehill College - 1972

CURRENT POSITION

President, E&S Environmental Chemistry, Inc. Dr. Sullivan co-founded this scientific research and consulting corporation in September, 1988.
President, E&S Environmental Restoration, Inc. Dr. Sullivan founded this environmental restoration corporation in June, 1996.

EXPERIENCE

Dr. Sullivan is President and Principal Scientist of E&S Environmental Chemistry, Inc. He has over 25 years of professional experience, including 12 years of environmental project management experience. His expertise includes the effects of air pollution on aquatic and terrestrial resources; watershed analysis; nitrogen cycling; aquatic acid/base chemistry; mobilization, speciation and toxicity of metals in acidic waters; episodic processes controlling surface water chemistry; and environmental assessment. He is author of the National Acid Precipitation Assessment Program (NAPAP) State of Science and Technology Report on past changes in surface water acid/base chemistry throughout the United States from acid deposition. In recent years, he has also been principal investigator for a comparison between paleolimnological reconstructions of lakewater acid/base chemistry and process-based model reconstructions (U.S. Department of Energy), incorporation of an organic acid submodel into the watershed model MAGIC and testing of the revised model using data from ecosystem manipulation experiments in Norway and the U.S. (U.S. Department of Energy), investigation of the role of land use and landscape in the acidification of surface waters (U.S. Department of Energy), an analysis of the feasibility of adopting standards for deposition of nitrogen and sulfur (U.S. EPA), and a variety of nonpoint source pollution studies in forest/agricultural watersheds. His research and project management experience includes the following:

- Served as Co-PI of Diatom Paleolimnology Data Cooperative, 1993-present, housed at the Academy of Natural Sciences in Philadelphia and funded by NOAA and NSF. This data cooperative disseminates lake sediment core paleolimnological data focused on past climate reconstructions to the climate modeling and research community (http://diatom.acnatsci.org/dpdc/).
- Served as project manager for preparation of an Air Quality Review for Class I national parks throughout California. Also co-authored similar reviews for the Pacific Northwest and the Rocky Mountain and Great Plains regions of the National Park Service.
- Coordinated and analyzed available data bases throughout the United States, and internationally, providing evidence regarding the extent and magnitude of surface

water acidification. Summarized and synthesized pertinent data and authored the State of Science and Technology Report for the National Acid Precipitation Assessment Program (NAPAP) on historical acidification.

- Served as project manager for a modeling project to assess aquatic and terrestrial effects of air pollutants throughout the southern Appalachian Mountains for the Southern Appalachian Mountain Initiative (SAMI).
- Served as lead author and individual responsible for synthesis and integration for report to the National Park Service on the sensitivity of natural resources in Shenandoah National Park to air pollution degradation.
- Coordinated research efforts of a team of experts in the fields of surface water chemistry, mathematical modeling, and paleoecology for the purpose of comparing paleoecological inferences and process-based model hindcasts of Adirondack Mountain lakewater chemistry. This project constitutes the most comprehensive, and only statistically-based, model validation exercise conducted to date for an acid-base chemistry watershed model. Supervised data analyses and interpretation, and served as lead author for final agency report.
- Directed field research project for the Alaska Department of Environmental Conservation on the Kenai Peninsula to investigate forest effects from industrial emissions of nitrogen. Coordinated and supervised all logistics and field sampling activities, including aerial infrared photography, measurements of forest growth and health, and collection of soil solution, conifer needles, precipitation, and throughfall. Directed data base construction, QA, data analyses, and interpretation; served as lead author on final report.
- Served as member of NAPAP's working group that prepared the aquatic portions of the 1990 Integrated Assessment (IA), NAPAP's final policy document for Congress. Drafted major portions of the IA; participated in a series of assessment meetings attended by federal, national laboratory and industry scientists, economists, and policy specialists; provided input on all aquatics sections of the final document. Also authored the aquatic sections of NAPAP’s 1996 Report to Congress.
- Served as project manager for the Tillamook Bay National Estuary Project for several water quality monitoring projects to evaluate the concentrations and loads of nutrients, sediment, and fecal coliform bacteria in the five rivers that flow into Tillamook Bay, Oregon. These projects include long-term monitoring, storm monitoring, source area identification, and evaluation of the relationships between land use and water quality.
- Served as project manager for E&S’s role in the construction and management of a diatom paleoclimate data cooperative for North and South America. The data cooperative brought together paleolimnological data from a multitude of sources that can be used to reconstruct aspects of historical regional climates from diatom remains in dated lake sediment cores.

AWARDS AND HONORS

Academic scholarship, Stonehill College, 1968-72
Massachusetts State Scholarship, 1969-72
Cum laude, Stonehill College, 1972

Postdoctoral fellowship, Royal Norwegian Council for Scientific and Industrial Research, 1984-86
Director's Technical Contribution Award, Corvallis Environmental Research Laboratory, U.S. EPA, 1987
Northrop Services, Inc., Best Orator, Effective Winning Presentations, 1987
Best Scientific Paper Award, Corvallis Environmental Research Laboratory, U.S. EPA, 1988

PUBLICATIONS

Books, Special Issues

Sullivan, T.J. 2005. Acidification - chronic. In: Lehr, J.H. and J. Keeley (Eds.). Water Encyclopedia: Surface and Agricultural Water. John Wiley & Sons.

Sullivan, T.J. 2000. Aquatic Effects of Acidic Deposition. Lewis Publ., Boca Raton, FL. 373 pp.

Seip, H.M., L. Pawlowski, and **T.J. Sullivan** (eds.). 1994. Environmental degradation due to heavy metals and acidifying deposition - A Polish-Scandinavian Workshop. Ecol. Engr. Special Issue. 3(3):205-314.

Pawlowski, L., H.M. Seip, and **T.J. Sullivan** (eds.). 1994. Aluminum in the environment. J. Ecol. Chem. 3(3).

Sullivan, T.J. and C. Moersch. 1993. Radon Alert (Teacher Guides for Junior High School Education). E&S Geographic and Information Services, Corvallis, OR. 2 vol., 204 pp.

Sullivan, T.J. and C. Moersch. 1992. Radon Alert (Teacher Guides for High School Education). E&S Geographic and Information Services, Corvallis, OR. 4 vol., 368 pp.

Sullivan, T.J. 1991. Oregon Coast Recreational Atlas. A Guide to Natural Resources and Recreational Opportunities. E&S Geographic and Information Services, Corvallis, OR. 106 pp.

NAPAP Aquatic Effects Working Group (Multiple authors including **Sullivan, T.J.**). 1991. National Acid Precipitation Assessment Program 1990 Integrated Assessment. National Acid Precipitation Assessment Program, Washington, DC. 520 pp.

Sullivan, T.J. 1990. Historical Changes in Surface Water Acid-Base Chemistry in Response to Acidic Deposition. State of the Science, SOS/T 11, National Acid Precipitation Assessment Program. 212 pp.

Journal Articles/Book Chapters

Sullivan, T.J., B.J. Cosby, B. Jackson, K.U. Snyder, and A.T. Herlihy. In review. Acidification and Prognosis for Future Recovery of Acid-Sensitive Streams in the Southern Blue Ridge Province.

Sullivan, T.J., B.J. Cosby, B. Jackson, and K.U. Snyder. In review. Critical Loads of Atmospheric Sulfur Deposition for the Protection and Recovery of Acid-Sensitive Streams in the Southern Blue Ridge Province.

Sullivan, T.J., B.J. Cosby, J.R. Webb, R.L. Dennis, A.J. Bulger, F.A. Deviney Jr. 2008. Streamwater acid-base chemistry and critical loads of atmospheric sulfur deposition in Shenandoah National Park, Virginia. Environ. Monit. Assess. 137:85-99. DOI 10:1007/s10661-007-9731-1

Zhai, J., C. T. Driscoll, **T. J. Sullivan**, and B. J. Cosby. 2008. Regional application of the PnET-BGC model to assess historical acidification of Adirondack lakes. Water Resour. Res., 44, W01421, doi:10.1029/2006WR005532.

McNeil, B.E., J.M. Read, **T.J. Sullivan**, T.C. McDonnell, I. J. Fernandez, and C.T. Driscoll. 2008. The spatial pattern of nitrogen cycling in the Adirondack Park, New York. Ecol. Appl. 18:438–452.

Sullivan, T.J., B.J. Cosby, A.T. Herlihy, C.T. Driscoll, I.J. Fernandez, T.C. McDonnell, C.W. Boylen, S.A. Nierzwicki-Bauer, and K.U. Snyder. 2007. Assessment of the extent to which intensively-studied lakes are representative of the Adirondack region and response to future changes in acidic deposition. Water Air Soil Pollut. 185:279-291.

Sullivan, T.J., J.R. Webb, K.U. Snyder, A.T. Herlihy, and B.J. Cosby. 2007. Spatial distribution of acid-sensitive and acid-impacted streams in relation to watershed features in the southern Appalachian Mountains. Water Air Soil Pollut. 182:57-71.

McNulty, S.G., E.C. Cohen, J.A. Moore Meyers, **T.J. Sullivan**, and H. Li. 2007. Estimates of critical acid loads and exceedances for forest soils across the conterminous United States. Environ. Poll. 149(3):281-292.

Sullivan, T.J., I.J. Fernandez, A.T. Herlihy, C.T. Driscoll, T.C. McDonnell, N.A. Nowicki, K.U. Snyder, and J.W. Sutherland. 2006. Acid-base characteristics of soils in the Adirondack Mountains, New York. Soil Sci. Soc. Amer. J. 70:141-152.

Sullivan, T.J., M. Wustenberg, K.U. Snyder, J. Moore, D. Moore, E. Gilbert, and E. Mallery. 2006. Relationship between size of vegetated buffers and transport of fecal coliform bacteria from pasturelands treated with dairy cow manure. Abstract. J. Dairy Sci. 89 (Suppl. 1): Abstract 298.

Sullivan, T.J., B.J. Cosby, K.A. Tonnessen, and D.W. Clow. 2005. Surface water acidification responses and critical loads of sulfur and nitrogen deposition in Loch Vale Watershed, Colorado. Water Resour. Res. 41:W01021, doi:10.1029/2004WR003414.

Sullivan, T.J., K. U. Snyder, E. Gilbert, J.M. Bischoff, M. Wustenberg, J. A. Moore, and D. Moore. 2005. Assessment of water quality in association with land use in the Tillamook Bay Watershed, Oregon. Water Air Soil Pollut. 161:3-23.

Sullivan, T.J., M.C. Saunders, B.L. Nash, K.A. Tonnessen, and B.J. Miller 2005. Application of a regionalized knowledge-based model for classifying the impacts of nitrogen, sulfur, and organic acids on lakewater chemistry. Knowledge Based Systems. 18(1):55-68.

Saunders, M.C., **T.J. Sullivan**, B.L. Nash, K.A. Tonnessen, and B.J. Miller. 2005. A knowledge-based approach for classifying lake water chemistry. Knowledge Based Systems. 18(1): 47-54.

Sullivan, T.J., B.J. Cosby, A.T. Herlihy, J.R. Webb, A.J. Bulger, K.U. Snyder, P.F. Brewer, E.H. Gilbert, and D.L. Moore. 2004. Regional model projections of future effects of sulfur and nitrogen deposition on streams in the southern Appalachian Mountains. Water Resour. Res. 40(2), W02101 doi:10.1029/2003WR001998.

Sullivan, T.J., M. Wustenberg, J. A. Moore, K. U. Snyder, E. Gilbert, D. Moore, and E. Mallery. 2004. Riparian plantings and fencing improve water quality in Tillamook River Watershed (Oregon). Ecolog. Restor. 22(2):138-140.

Sullivan, T.J., D.F. Charles, J.A. Bernert, B. McMartin, K.B. Vaché, and J. Zehr. 1999. Relationship between landscape characteristics, history, and lakewater acidification in the Adirondack Mountains, New York. Water Air Soil Pollut. 112:407-427.

Sullivan, T.J. and B.J. Cosby. 1998. Modeling the Concentration of Aluminum in Surface Waters. Water Air Soil Pollut. 105:643-659.

Sinha, R., M.J. Small, P.F. Ryan, **T.J. Sullivan**, and B.J. Cosby. 1998. Reduced-form modeling of surface water and soil chemistry for the Tracking and Analysis Framework. Water Air Soil Pollut. 105:617-642.

Sullivan, T.J. 1997. Ecosystem manipulation experimentation as a means of testing a biogeochemical model. Environ. Mgmt. 21(1):15-21.

Sullivan, T.J., J.M. Eilers, B.J. Cosby, and K.B. Vaché. 1997. Increasing role of nitrogen in the acidification of surface waters in the Adirondack Mountains, New York. Water Air Soil Pollut. 95:313-336.

Bernert, J.A., J.M. Eilers, **T.J. Sullivan**, K.E. Freemark, and C. Ribic. 1997. A quantitative method for delineating regions: an example for the Western Corn Belt Plains Ecoregion of the USA. Environ. Mgmt. 21:405-420.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, D.F. Charles, and H.F. Hemond. 1996. Influence of organic acids on model projections of lake acidification. Water Air Soil Pollut. 91:271-282.

Sullivan, T.J., B. McMartin, and D.F. Charles. 1996. Re-examination of the role of landscape change in the acidification of lakes in the Adirondack Mountains, New York. Sci. Total Environ. 183(3):231-248.

Sullivan, T.J. and B.J. Cosby. 1995. Testing, improvement, and confirmation of a watershed model of acid-base chemistry. Water Air Soil Pollut. 85:2607-2612.

Sullivan, T.J. 1994. Progress in quantifying the role of aluminum in acidification of surface waters. J. Ecol. Chem. 3:157-168.

Sullivan, T.J. 1994. Evaluation of biogeochemical models using data from experimental ecosystem manipulations. In Jenkins, A., R.C. Ferrier, and C. Kirby. Ecosystem

Manipulation Experiments: Scientific Approaches, Experimental Design, and Relevant Results. Ecosystems Research Report No. 20. ECSC-EC-EAEC, Brussels. pp. 344-352.

Sullivan, T.J., B.J. Cosby, S.A. Norton, D.F. Charles, R.F. Wright, and E. Gjessing. 1994. Multi-site testing and evaluations of a geochemical model of acid-base chemistry: confirmation of the MAGIC model using catchment manipulation experiments and historical diatom inferences. In Jenkins, A., R.C. Ferrier, and C. Kirby. Ecosystem Manipulation Experiments: Scientific Approaches, Experimental Design, and Relevant Results. Ecosystems Research Report No. 20. ECSC-EC-EAEC, Brussels. pp. 360-365.

Driscoll, C.T., M.D. Lehtinen, and **T.J. Sullivan**. 1994. Modeling the acid-base chemistry of organic solutes in Adirondack, New York, lakes. Water Resour. Res. 30:297-306.

Sullivan, T.J. and D.F. Charles. 1994. The feasibility and utility of a paleolimnology/ paleoclimate data cooperative for North America. J. Paleolimnol. 10:265-273.

Sullivan, T.J. 1993. Whole ecosystem nitrogen effects research in Europe. Environ. Sci. Technol. 27(8):1482-1486.

Sullivan, T.J., R.S. Turner, D.F. Charles, B.F. Cumming, J.P. Smol, C.L. Schofield, C.T. Driscoll, B.J. Cosby, H.J.B. Birks, A.J. Uutala, J.C. Kingston, S.S. Dixit, J.A. Bernert, P.F. Ryan, and D.R. Marmorek. 1992. Use of historical assessment for evaluation of process-based model projections of future environmental change: Lake acidification in the Adirondack Mountains, New York, U.S.A. Environ. Poll. 77:253-262.

Turner, R.S., P.F. Ryan, D.R. Marmorek, K.W. Thornton, **T.J. Sullivan**, J.P. Baker, S.W. Christensen, and M.J. Sale. 1992. Sensitivity to change for low-ANC eastern US lakes and streams and brook trout populations under alternative sulfate deposition scenarios. Environ. Poll. 77:269-277.

Sullivan, T.J. 1991. Long-term temporal trends in surface water chemistry. pp. 615-639. In: Charles, D.F. (Ed.), Acid Deposition and Aquatic Ecosystems: Regional Case Studies, Springer-Verlag, New York.

Husar, R.B., **T.J. Sullivan**, and D.F. Charles. 1991. Methods for evaluation of historical change. pp. 65-82. In: Charles, D.F. (Ed.), Acid Deposition and Aquatic Ecosystems: Regional Case Studies, Springer-Verlag, New York.

Eilers, J.M., **T.J. Sullivan**, and K.C. Hurley. 1990. The most dilute lake in the world? Hydrobiologia 199:1-6.

Sullivan, T.J., D.F. Charles, J.P. Smol, B.F. Cumming, A.R. Selle, D.R. Thomas, J.A. Bernert, and S.S. Dixit. 1990. Quantification of changes in lakewater chemistry in response to acidic deposition. Nature 345:54-58.

Sullivan, T.J., D.L. Kugler, M.J. Small, C.B. Johnson, D.H. Landers, B.J. Rosenbaum, W.S. Overton, W.A. Kretser, and J. Gallagher. 1990. Variation in Adirondack, New York, lakewater chemistry as a function of surface area. Water Resour. Bull. 26:167-176.

Seip, H.M., D.O. Anderson, N. Christophersen, **T.J. Sullivan**, and R.D. Vogt. 1989. Variations in concentrations of aqueous aluminum and other chemical species during hydrological episodes at Birkenes, southernmost Norway. J. Hydrol. 108:387-405.

Johnson, C.B., **T.J. Sullivan**, and D.J. Blick. 1989. Defining regional populations of lakes for the assessment of surface water quality. Water Resour. Bull. 25:1-8.

Seip, H.M., N. Christophersen, and **T.J. Sullivan**. 1989. Episodic variations in streamwater aluminum chemistry at Birkenes, southernmost Norway. pp. 159-169. In: Lewis, T.E. (Ed.), Environmental Chemistry and Toxicology of Aluminum, Lewis Publishers Inc., Chelsea, MI.

Sullivan, T.J., C.T. Driscoll, S.A. Gherini, R.K. Munson, R.B. Cook, D.F. Charles, and C.P. Yatsko. 1989. The influence of organic acid anions and aqueous aluminum on measurements of acid neutralizing capacity in surface waters. Nature 338:408-410.

Sullivan, T.J., J.M. Eilers, M.R. Church, D.J. Blick, K.N. Eshleman, D.H. Landers, and M.S. DeHaan. 1988. Atmospheric wet sulfate deposition and lakewater chemistry. Nature 331:607-609.

Sullivan, T.J., C.T. Driscoll, J.M. Eilers, and D.H. Landers. 1988. Evaluation of the role of sea salt inputs in the long-term acidification of coastal New England lakes. Environ. Sci. Technol. 22:185-190.

Muniz, I.P., R. Andersen, and **T.J. Sullivan**. 1987. Physiological response of brown trout spawners and post-spawners to acidic streamwater. Water Air Soil Pollut. 36:371-379.

Seip, H.M., N. Christophersen, and **T.J. Sullivan**. 1987. Episodic variations in streamwater aluminum chemistry at Birkenes, southernmost Norway. Preprint extended abstract. Amer. Chem. Soc. Meeting, New Orleans, August 30-Sept. 4.

Andersen, R., Ø. Haraldstad, I.P. Muniz, and **T.J. Sullivan**. 1987. Effects of shellsand on water quality and mature brown trout. Fauna 40:150-159 (in Norwegian).

Sullivan, T.J., I.P. Muniz, and H.M. Seip. 1986. A comparison of frequently used methods for the determination of aqueous aluminum. Int. J. Environ. Anal. Chem. 26:61-75.

Sullivan, T.J., N. Christophersen, I.P. Muniz, H.M. Seip and P.D. Sullivan. 1986. Aqueous aluminum chemistry response to episodic increases in discharge. Nature 323:324-327.

Røyset, O. and **T.J. Sullivan**. 1986. Effect of dissolved humic compounds on the determination of aqueous aluminum by three spectrophotometric methods. Int. J. Environ. Anal. Chem. 27:305-14.

Sullivan, T.J. and M.C. Mix. 1985. Persistence and fate of polynuclear aromatic hydrocarbons deposited on slash burn sites in the Cascade Mountains and Coast Range of Oregon. Arch. Environ. Contam. Toxicol. 14:187-192.

Sullivan, T.J. and M.C. Mix. 1983. Pyrolytic deposition of polynuclear aromatic hydrocarbons due to slash burning on clear-cut sites. Bull. Environ. Contam. Toxicol. 31:207-215.

Sullivan, T.J. and M.C. Mix. 1983. A simple and inexpensive method for measuring integrated light energy. Environ. Sci. Technol. 17:127-128.

Sullivan, T.J. 1982. Avian species diversity: Its relation to the competition hypothesis. Proc. Oregon Acad. Sci. 18:10-20

Sullivan, T.J. 1977. Avian and mammalian distribution in the Powderhorn Primitive Area, Colorado. M.A. thesis. Western State College, Gunnison, CO. 209 pp.

Reports

Sullivan, T.J., B.J. Cosby, K.U. Snyder, A.T. Herlihy, B. Jackson. 2007. Model-Based Assessment of the Effects of Acidic Deposition on Sensitive Watershed Resources in the National Forests of North Carolina, Tennessee, and South Carolina. Final report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., A.T. Herlihy. 2007. Air Quality Related Values and Development of Associated Protocols for Evaluation of the Effects of Atmospheric Deposition on Aquatic and Terrestrial Resources on Forest Service Lands. Final report prepared for the U.S.D.A Forest Service.

Sullivan, T.J. 2007. What's up with the Air? Shenandoah National Park. National Park Service, Luray, VA.

Sullivan, T.J., C.T. Driscoll, B.J. Cosby, I.J. Fernandez, A.T. Herlihy, J. Zhai, R. Stemberger, K.U. Snyder, J.W. Sutherland, S.A. Nierzwicki-Bauer, C.W. Boylen, T.C. McDonnell, and N.A. Nowicki. 2006. Assessment of the Extent to Which Intensively-Studied Lakes are Representative of the Adirondack Mountain Region. Final Report 06-17. New York State Energy Research and Development Authority, Albany, NY.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Lower Umpqua River Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Mill Creek Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Middle Umpqua River Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Upper Umpqua River Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J. and B.J. Cosby. 2004. Aquatic critical load development for the Monongahela National Forest, West Virginia. Report Prepared for USDA Forest Service, Monongahela National Forest, Elkins, WV. E&S Environmental Chemistry, Inc., Corvallis, OR.

Webb, J.R., **T.J. Sullivan**, and B. Jackson. 2004. Assessment of Atmospheric Deposition Effects on National Forests. Protocols for Collection of Supplemental Stream Water and Soil Composition Data for the MAGIC Model. Report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., B.J. Cosby, J.A. Lawrence, R.L. Dennis, K. Savig, J.R. Webb, A.J. Bulger, M. Scruggs, C. Gordon, J. Ray, E.H. Lee, W.E. Hogsett, H. Wayne, D. Miller, and J.S. Kern. 2003. Assessment of Air Quality and Related Values in Shenandoah National Park. Technical Report NPS/NERCHAL/NRTR-03/090. U.S. Department of the Interior, National Park Service, Northeast Region, Philadelphia, PA.

Snyder, K.U., **T.J. Sullivan**, D.L. Moore, R.B. Raymond, and E.H. Gilbert. 2003. Trask River Watershed Analysis. Report submitted to Oregon Department of Forestry and U.S. Department of Interior, Bureau of Land Management. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J. and B.J. Cosby. 2002. Critical loads of sulfur deposition to protect streams within Joyce Kilmer And Shining Rock Wilderness Areas from future acidification. Report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., D.W. Johnson, and R. Munson. 2002. Assessment of Effects of Acid Deposition on Forest Resources in the Southern Appalachian Mountains. Report prepared for the Southern Appalachian Mountains Initiative (SAMI). E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., B.J. Cosby, J.R. Webb, K.U. Snyder, A.T. Herlihy, A.J. Bulger, E.H. Gilbert, and D. Moore. 2002. Assessment of the Effects of Acidic Deposition on Aquatic Resources in the Southern Appalachian Mountains. Report prepared for the Southern Appalachian Mountains Initiative (SAMI). E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., M. Wustenberg, K.U. Snyder, J. Moore, D. Moore, E. Gilbert, and E. Mallery. 2002. Remediation of Agricultural Contributions of Fecal Coliform Bacteria, Sediment, and Heat in the Tillamook Basin: Final Report and Conclusions of the Beaver Creek Project. E&S Environmental Restoration, Inc., Corvallis, OR.

Sullivan, T.J., E.H. Gilbert, and K.U. Snyder. 2002. Results of storm-based monitoring of water quality In the Tillamook, Kilchis, Trask, and Wilson Rivers, Tillamook Basin, Oregon from 1996 to 2002. State of the Bay Report. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K.U., **T.J. Sullivan**, R.B. Raymond, D. Moore, and E. Gilbert. 2002. North Santiam River Watershed Assessment. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K.U., **T.J. Sullivan**, R.B. Raymond, E. Gilbert, and D. Moore. 2002. Necanicum River Watershed Assessment. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., D.L. Peterson, C.L. Blanchard, K. Savig, and D. Morse. 2001. Assessment of Air Quality and Air Pollutant Impacts in Class I National Parks of California. NPS D-1454. U.S. Dept. of the Interior, National Park Service, Air Resources Division.

Sullivan, T.J., J.M. Bischoff, K.U. Snyder, R.B. Raymond, S. White, and S.K. Binder. 2001. Wilson River Watershed Assessment. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K.U., **T.J. Sullivan**, R.B. Raymond, J.M. Bischoff, S. White, and S.K. Binder. 2001. Miami River Watershed Assessment. E&S Environmental Chemistry, Inc., Corvallis, OR.

Cosby, B.J. and **T.J. Sullivan**. 2001. Quantification of dose-response relationships and critical loads of sulfur and nitrogen for six headwater catchments in Rocky Mountain, Grand Teton, Sequoia, and Mount Rainier National Parks. Report 97-15-01. E&S Environmental Chemistry, Inc., Corvallis, OR.

Cosby, B.J. and **T.J. Sullivan**. 1999. Application of the MAGIC Model to Selected Catchments: Phase I. Southern Appalachian Mountains Initiative (SAMI). Final Report submitted to Southern Appalachian Mountains Initiative. University of Virginia, Charlottesville.

Bernert, J.A. and **T.J. Sullivan**. 1998. Bathymetric analysis of Tillamook Bay. Comparison among bathymetric databases collected in 1867,1957, and 1995. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J. and J.M. Eilers. 1998. River water quality monitoring plan for the Tillamook Bay National Estuary Project. Report No. 97-16-01 to Tillamook Bay National Estuary Project. E&S Environmental Chemistry, Inc.

Sullivan, T.J., J. M. Bischoff, K.B. Vaché, M. Wustenberg, and J. Moore. 1998. Water quality monitoring in the Tillamook Watershed. Results of a one-year periodic monitoring and storm sampling program. Report to Tillamook Bay National Estuary Project. E&S Environmental Chemistry, Inc.

Sullivan, T.J., J.M. Bischoff, and K.B. Vaché. 1998. Results of storm sampling in the Tillamook Bay Watershed. Report to Tillamook Bay National Estuary Project. E&S Environmental Chemistry, Inc.

Sullivan, T.J., B.J. Cosby, J.A. Bernert, and J.M. Eilers. 1998. Model evaluation of dose/response relationships and critical loads for nitrogen and sulfur deposition to the watersheds of Lower Saddlebag and White Dome Lakes. Report No. 97-10-01 to U.S.D.A. Forest Service. E&S Environmental Chemistry, Inc.

Peterson, D.L., **T.J. Sullivan**, J.M. Eilers, S. Brace, D. Horner, and K. Savig. 1998. Assessment of Air Quality and Air Pollutant Impacts in National Parks of the Rocky Mountains and Northern Great Plains. NPS D-657. U.S. Dept. of the Interior, National Park Service, Air Resources Division.

Bernert, J.A. and **T.J. Sullivan**. 1997. Quality Assurance Plan for the Tillamook Bay National Estuary Program. River Water Quality Monitoring Project. Report Number 96-20-01. E&S Environmental Chemistry, Inc.

Bloyd, C., J. Camp, G. Conzelmann, J. Formento, J. Molburg, J. Shannon, M. Henrion, R. Sonnenblick, K. Soo Hoo, J. Kalagnanam, S. Siegel, R. Sinha, M. Small, **T. Sullivan**, R. Marricio, P. Ryan, R. Turner, D. Austin, D. Burtraw, D. Farrell, T. Green, A. Krupnick and E. Mansur. 1996. Tracking and Analysis Framework (TAF) Model Documentation and User's Guide. An Interactive Model for Integrated Assessment of Title IV of the Clean Air Act Amendments. ANL/DIS/TM-36. Work sponsored by U.S. Department of Energy.

Sullivan, T.J. and D.F. Charles. 1995. The Role of Landscape Change in Surface Water Acidification. Report prepared for U.S. Department of Energy. DOE/ER/30196-6.

Sullivan, T.J. and B.J. Cosby. 1995. MAGIC Model Applications for Surface and Soil Waters as Input to the Tracking and Analysis Framework (TAF). Model Documentation. Report prepared for U.S. Department of Energy. DOE/ER/30196-7.

Eilers, J.M., C.L. Rose, and **T.J. Sullivan**. 1994. Status of air quality and effects of atmospheric pollutants on ecosystems in the Pacific Northwest Region of the National Park Service. Final Report submitted to the Air Quality Division, National Park Service, Denver, CO.

Sullivan, T.J., R.B. Raymond, J.A. Bernert, M. Gallagher, and J.M. Eilers. 1994. Watershed planning in Polk County. Final Report prepared for Polk County, City of Dallas, and Polk Soil and Water Conservation District.

Sullivan, T.J. and J.M. Eilers. 1994. Assessment of Deposition Levels of Sulfur and Nitrogen Required to Protect Aquatic Resources in Selected Sensitive Regions of North America. Final Report prepared for Technical Resources, Inc., Rockville, MD, Under Contract to U.S. Environmental Protection Agency, Environmental Research Laboratory-Corvallis, Corvallis, OR.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, H.F. Hemond, D.F. Charles, S.A. Norton, H.M. Seip, and G. Taugbøl. 1994. Confirmation of the MAGIC Model Using Independent Data: Influence of Organic Acids on Model Estimates of Lakewater Acidification. Report No. DOE/ER/30196-4. Final Report prepared for The U.S. Department of Energy, under Agreement No. DE-FG02-92ER30196.

Sullivan, T.J. and J.M. Eilers. 1992. Nitrogen effects studies in Europe. An evaluation of recent and on-going aquatic and terrestrial effects research projects. Report prepared for National Acid Precipitation Assessment Program. E&S Environmental Chemistry, Inc., Corvallis, OR.

Bernert, J.A., J.M. Eilers, K.J. Dueker, R. Vrana, R. Lycan, W.J. Ripple, and **T.J. Sullivan**. 1992. United States Fish and Wildlife Service, Region I. Geographic Information System Requirements Analysis/Strategic Plan. E&S Environmental Chemistry, Inc., Corvallis, OR

Sullivan, T.J., J. A. Bernert, E. A. Jenne, J. M. Eilers, B. J. Cosby, D. F. Charles, and A. R. Selle. 1991. Comparison of MAGIC and diatom paleolimnological model hindcasts of lakewater acidification in the Adirondack region of New York. Prepared for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830. Pacific Northwest Laboratory, Richland, WA.

Eilers, J.M., F.A. Vertucci, and **T.J. Sullivan**. 1991. Lake chemistry in the Sawtooth Mountains, Idaho: monitoring issues in wilderness areas. Report #91-13, to the Sawtooth National Forest, Twin Falls, ID. E&S Environmental Chemistry, Inc., Corvallis, OR. 29 pp.

Sullivan, T.J., C.L. Rose, R.E. Gilfilian, J.M. Eilers, N. van Breemen, J.A. Bernert, D. Hanson, and B.E. Queitzsch. 1990. Nikiski Vegetation Impact Assessment. Executive Summary Report. Prepared for the Alaska Department of Environmental Conservation, Juneau, Alaska.

Sullivan, T.J., B.J. Cosby, J.A. Bernert, E.A. Jenne, J.M. Eilers, D.F. Charles, and A.R. Selle. 1990. Comparison of paleolimnological and MAGIC model estimates of lakewater acidification in the Adirondack region. Acidic Deposition State of Science and Technology International Conference, Poster presentation, National Acid Precipitation Assessment Program; Hilton Head, South Carolina.

Bernert, J.A. and **T.J. Sullivan**. 1990. Historical Adirondack paleolimnological data base users guide. Report 90-02, E&S Environmental Chemistry, Inc., Corvallis, OR.

Pollman, C.D., D.A. Graetz, F.V. Ramsey, K.R. Reddy, and **T.J. Sullivan**. 1988. Feasibility of sediment removal and reuse for the restoration of Lake Apopka: Final Report for St. Johns River Water Management District. KBN Engineering and Applied Sciences, Inc., Gainesville, Florida.

Sullivan, T.J., H.M. Seip, and R.D. Vogt. 1987. Episodic changes in aluminum concentrations and other important parameters in stream and soil water in the Birkenes catchment, southernmost Norway. SI-Report 850701-2, Center for Industrial Research, Oslo.

Sullivan, T.J., N. Christophersen, and I.P. Muniz. 1987. Soil and streamwater chemistry during snowmelt at the Birkenes catchment, southernmost Norway, SI-Report 850701-1, Center for Industrial Research, Oslo.

Marmorek, D.R., D.P. Bernard, M.L. Jones, L.P. Rattie, and **T.J. Sullivan**. 1987. The Effects of Mineral Acid Deposition on Concentrations of Dissolved Organic Acids in Surface Waters. ESSA Environ. Social Syst. Anal., Ltd., Vancouver, B.C., Canada, 110 pp.

Presentations at National and International Conferences

McNulty, S., E. Cohen, H. Li, J. Moore Myers, and **T. Sullivan**. 2008. Estimates of critical acid loads and exceedances for forest soils across the conterminous United States. Paper presented at the 23rd International Union of Forest Research Organizations (IUFRO) Conference, Air Pollution and Climate Change at Contrasting Altitude and Latitude, September 7-12, 2008, Murten, Switzerland.

Sullivan, T.J. and B.J. Cosby. 2006. MAGIC model calculations of critical loads of acidic deposition for the protection of U.S. surface waters. Multi-Agency Critical Loads Workshop on Sulfur and Nitrogen Deposition Effects on Freshwater and Terrestrial Ecosystems, Charlottesville, VA, May 23-24, 2006.

Sullivan, T.J., B.J. Cosby, and C.T. Driscoll. Calculation of critical loads of acidic deposition for the protection of acid-sensitive surface waters. Paper presented at NADP 2006: Effects of Deposition in Coastal and Urban Environments, October 24-26, 2006, Norfolk, VA.

Herlihy, A., R. Hughes, and **T. Sullivan**. 2006. Developing reference conditions, indicators, field methodology, and indices of biotic integrity for a national lakes survey. Planning a Survey of the Nation's Lakes. National conference co-sponsored by U.S. Environmental Protection Agency, Chicago Botanic Garden, and North American Lake Management Society. Chicago, IL. April 25-28, 2006.

Sullivan, T.J., M. Wustenberg, K.U. Snyder, J. Moore, D. Moore, E. Gilbert, and E. Mallery. 2006. Relationship between size of vegetated buffers and transport of fecal coliform bacteria from pasturelands treated with dairy cow manure. Paper presented at American Dairy Science Association/American Society of Animal Science Association Joint Meeting, July 9-13, 2006, Minneapolis, MN.

Sullivan, T., C. Boyle, B.J. Cosby, C. Driscoll, I. Fernandez, A. Herlihy, T. McDonnell, E. Miller, S. Nierzwicki-Bauer, N. Nowicki, K. Snyder, R. Stemberger, and J. Sutherland. 2003. Assessment of extent to which intensively-studied lakes are representative of the Adirondack Mountain region, New York. Poster Presentation, American Geophysical Union, San Francisco, 8-12 December, 2003.

Sullivan, T.J., J.A. Bernert, M. Wustenberg, and J. Moore. Assessment of Water Quality in the Five Major Rivers that Flow into Tillamook Bay. 20th Annual Meeting, Pacific Estuarine Research Society, Tillamook, OR, May 15-17, 1997.

Sullivan, T.J. and B.J. Cosby. Testing, Improvement, and Confirmation of a Watershed Model of Acid-Base Chemistry. 5th Intern. Conf. on Acidic Deposition, Gothenberg, Sweden, 26-30 June, 1995.

Sullivan, T.J. and J.M. Eilers. Ecological effects of sulfur and nitrogen deposition in the Pacific Northwest Region. Meeting of the International Joint Commission, Vancouver, BC, Canada, October, 1995 (Invited).

Sullivan, T.J. Acid Rain as a Threat to Aquatic Resources. Sustainable Society and Protected Areas. 8th Conference on Research and Resource Management in Parks and on Public Lands, Portland, OR, April 17-21, 1995.

Sullivan, T.J., B.J. Cosby, S.A. Norton, D.F. Charles, R.F. Wright, and E. Gjessing. Multisite testing and evaluation of a geochemical model of acid-base chemistry: Confirmation of the MAGIC model using catchment manipulation experiments and historical diatom inferences. Poster presentation, Third International Symposium on Ecosystem Manipulation, Windermere, England, October 1994.

Sullivan, T.J. Evaluation of biogeochemical models using data from experimental ecosystem manipulations. Third International Symposium on Ecosystem Manipulation, Windermere, England, October, 1994 (Invited).

Sullivan, T.J. Progress in quantifying the role of aluminum in acidification of surface and soil waters. Intern. Conf. on Aluminum in the Environment, Lublin, Poland, 19-22 September, 1994 (Invited).

Sullivan, T.J., R.S. Turner, D.F. Charles, B.F. Cumming, J.P. Smol, C.L. Schofield, C.T. Driscoll, B.J. Cosby, H.J.B. Birks, A.J. Uutala, J.C. Kingston, S.S. Dixit, J.A. Bernert, P.F. Ryan, and D.R. Marmorek. 1992. Use of historical assessment for evaluation of process-based model projections of future environmental change: Lake acidification in the Adirondack Mountains, New York, U.S.A. 4th Intern. Conf. on Acidic Deposition, Glasgow, Scotland, 1990.

Sullivan, T.J., B.J. Cosby, J.A. Bernert, E.A. Jenne, J.M. Eilers, D.F. Charles, and A.R. Selle. 1990. Comparison of paleolimnological and MAGIC model estimates of lakewater acidification in the Adirondack region. Acidic Deposition State of Science and Technology International Conference, Poster presentation, National Acid Precipitation Assessment Program; Hilton Head, South Carolina.

Sullivan, T.J. 1990. Historical changes in the acid-base chemistry of lakes and streams throughout the United States. Acidic Deposition, State of Science and Technology International Conference, Hilton Head, South Carolina (Invited).

Sullivan, T.J. Aqueous aluminum speciation in acidified areas of southernmost Norway. Presented at Norwegian Chemical Society, Annual Meeting, Oslo. April, 1986.

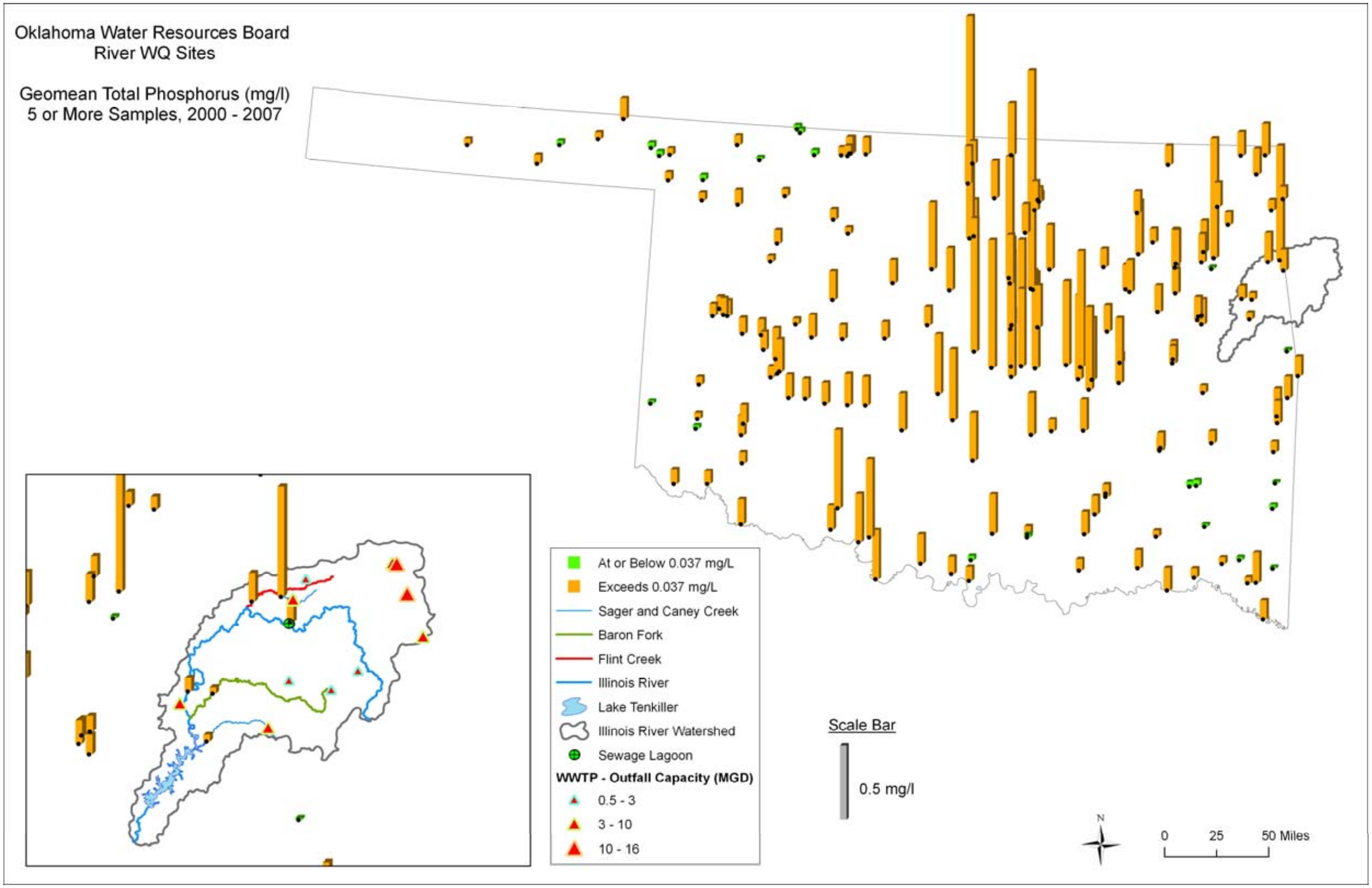

Figure 2-1. Map showing the geomean of total phosphorus concentration measured at all sites in Oklahoma represented in OWRB's database by five or more samples. The height of each bar is proportional to the geomean concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the 0.037 mg/L standard are shown in orange; those that do not exceed the standard are shown in green. The one very high bar within the IRW is located on Sager Creek, approximately 3 miles below the Siloam Springs WWTP.

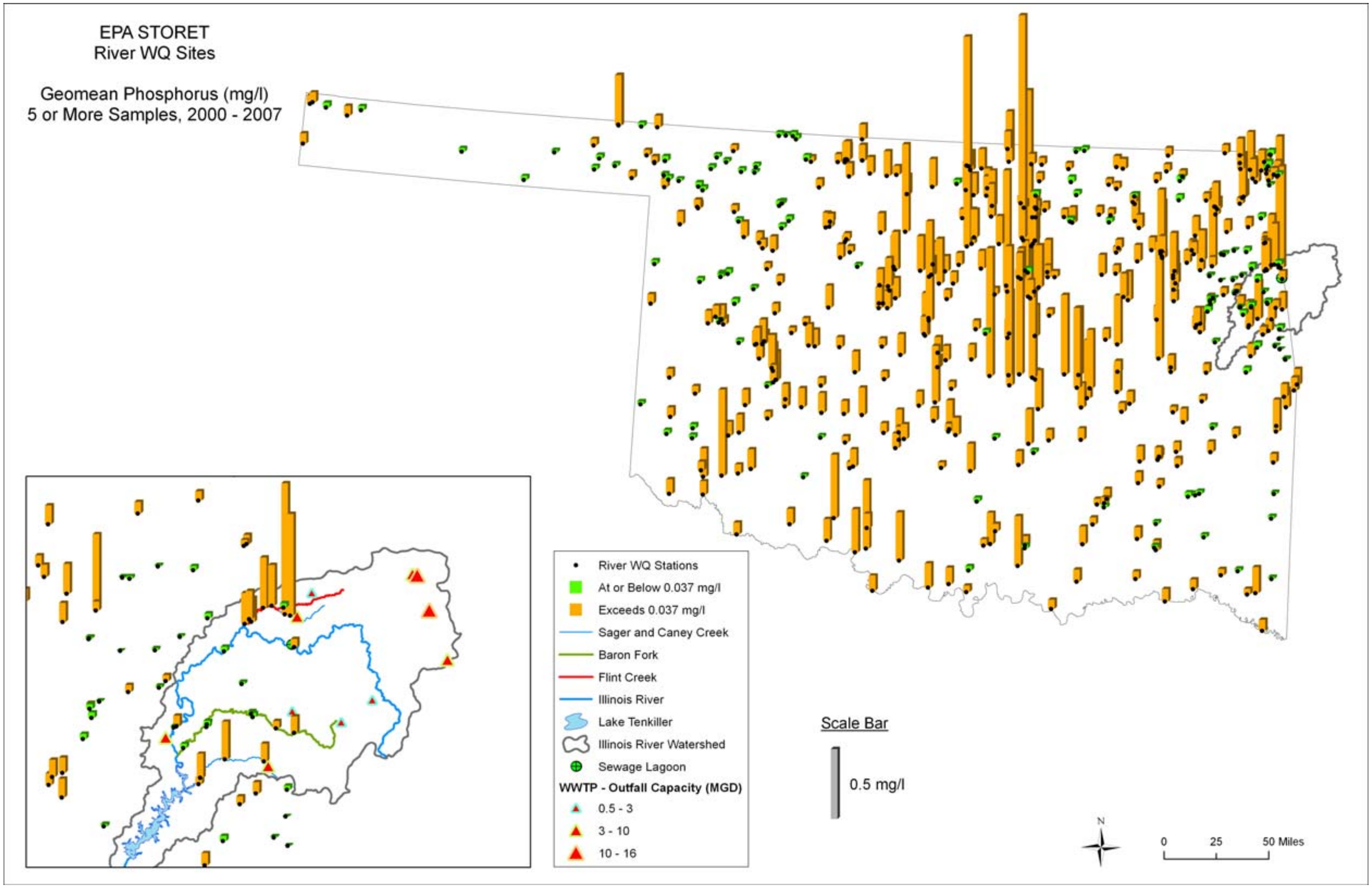

Figure 2-2. Map showing the geomean of phosphorus concentration measured at all sites in Oklahoma represented in EPA's STORET database by five or more samples. The height of each bar is proportional to the geomean concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the 0.037 mg/L standard are shown in orange; those that do not exceed the standard are shown in green. The two very high bars within the IRW are located on Sager Creek, one approximately 1.5 miles and one approximately 3 miles below the Siloam Springs WWTP.

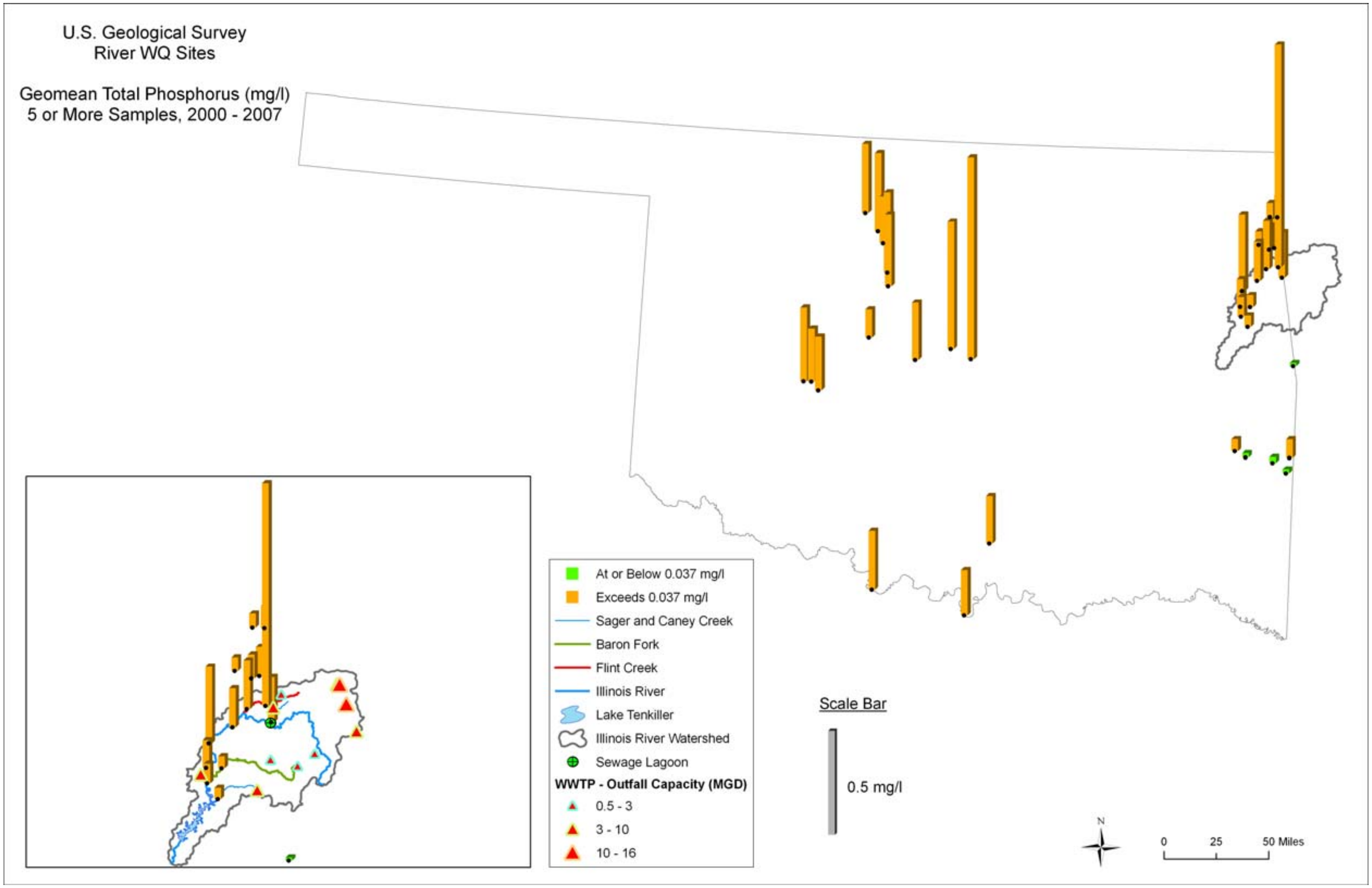

Figure 2-3. Map showing the geomean of total phosphorus concentration measured at all sites in Oklahoma represented in USGS's database by five or more samples. The height of each bar is proportional to the geomean concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the 0.037 mg/L standard are shown in orange; those that do not exceed the standard are shown in green. The one very high bar within the IRW is located on Sager Creek, approximately 3 miles below the Siloam Springs WWTP.

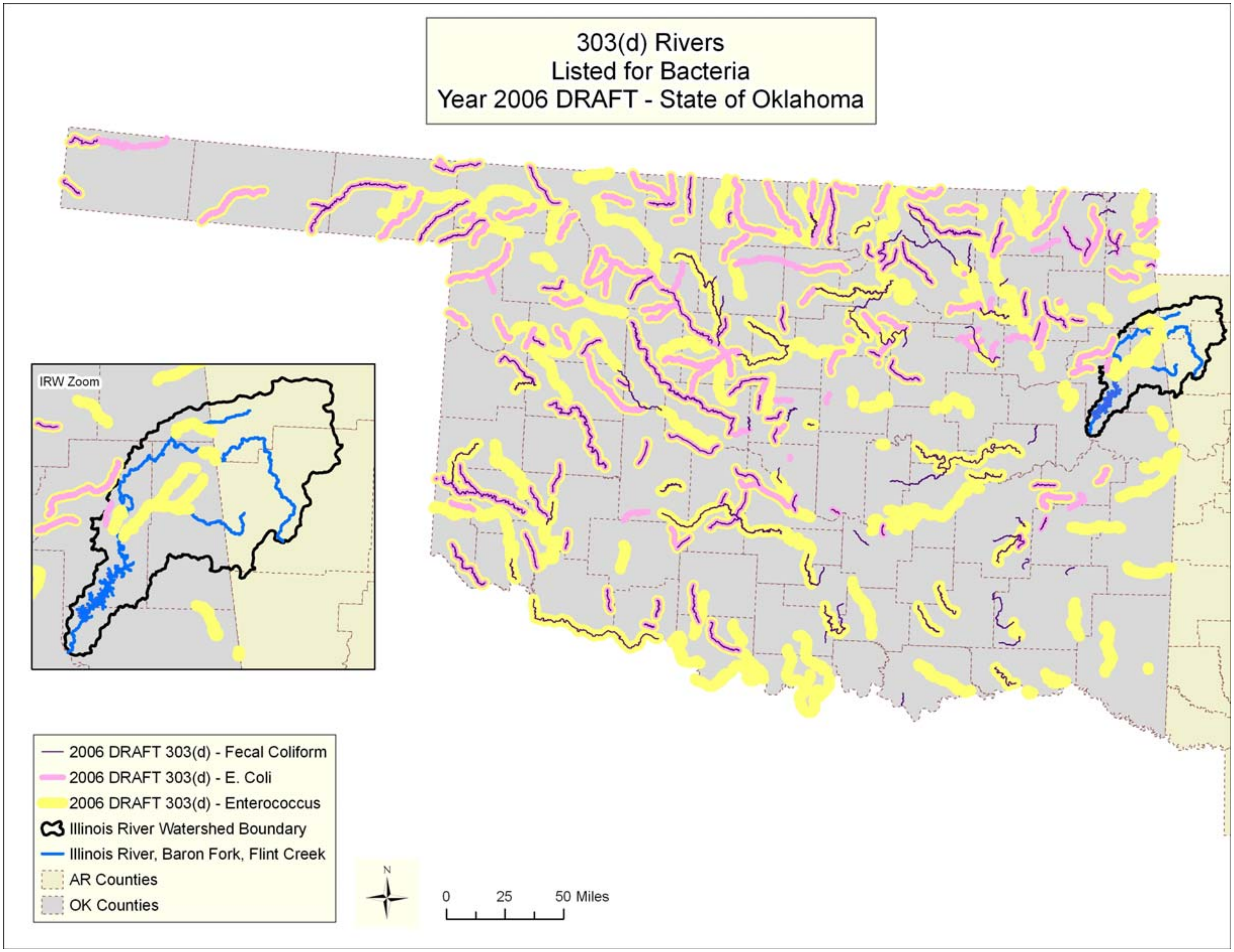

Figure 2-4. Streams within Oklahoma that are 303(d) listed for bacteria, based on the 2006 303(d) list. Listings are shown separately for fecal coliform bacteria, *E. coli*, and enterococcus. Listings are widespread throughout the state. The spatial data for 2008 303(d) listings were not available at the time this map was produced. (Source: Oklahoma Department of Environmental Quality)

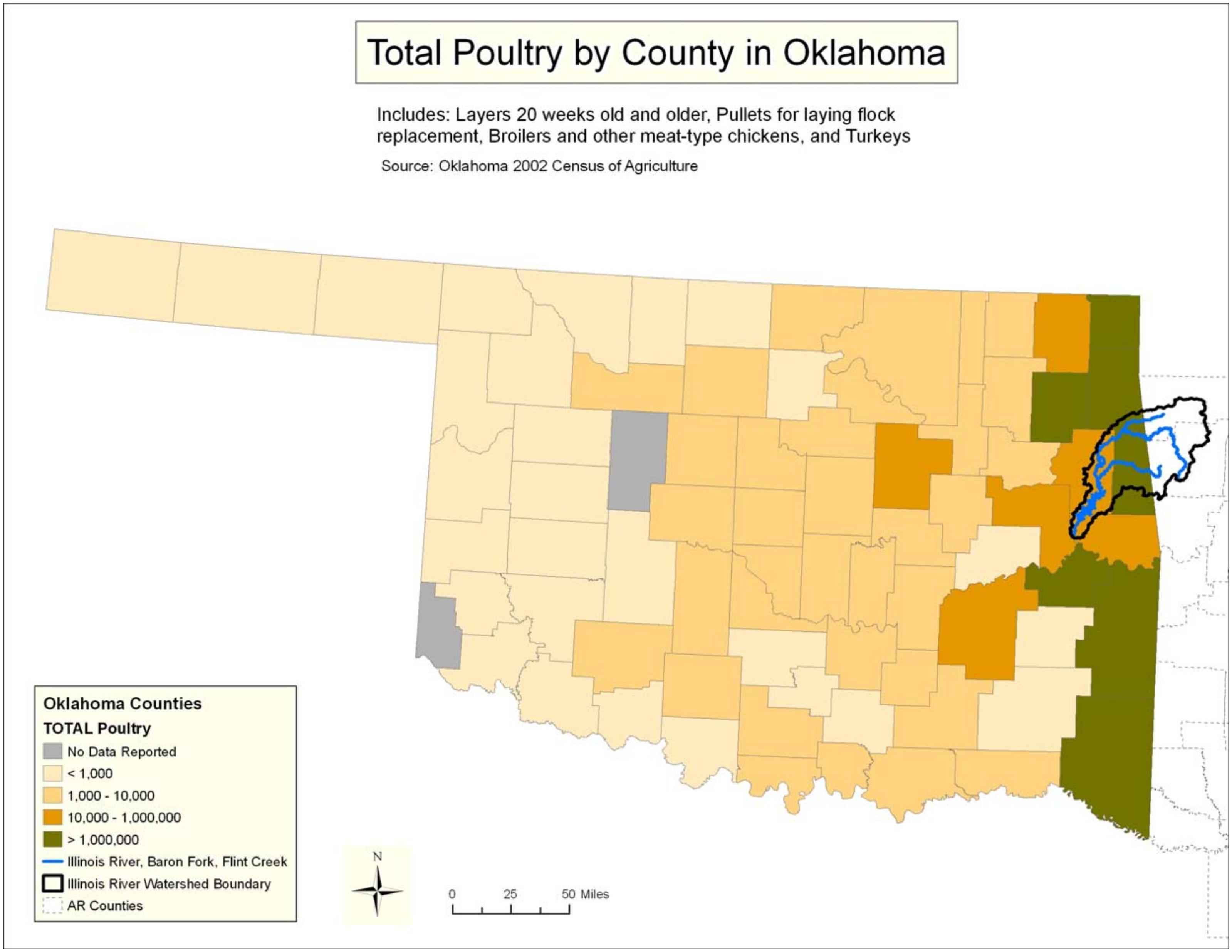

Figure 2-5. **Number of poultry in Oklahoma, by county, from the agricultural census data in 2002 and discussion with Dr. Billy Clay. Based on these data, the poultry industry is mainly confined to eastern Oklahoma.**

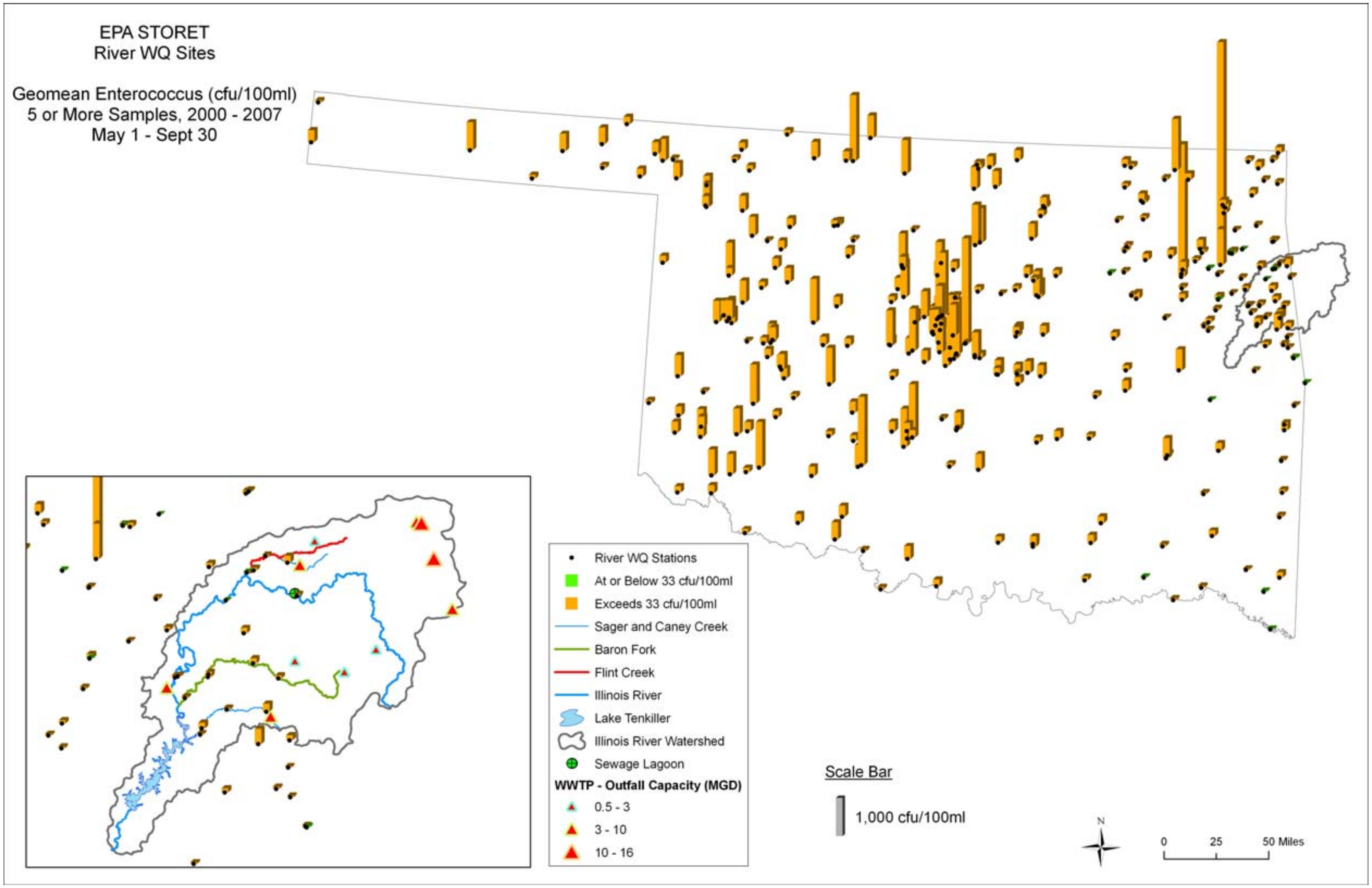

Figure 2-6. Map showing the geomean of enterococcus bacteria concentrations measured at all sites in Oklahoma represented in EPA's STORET database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

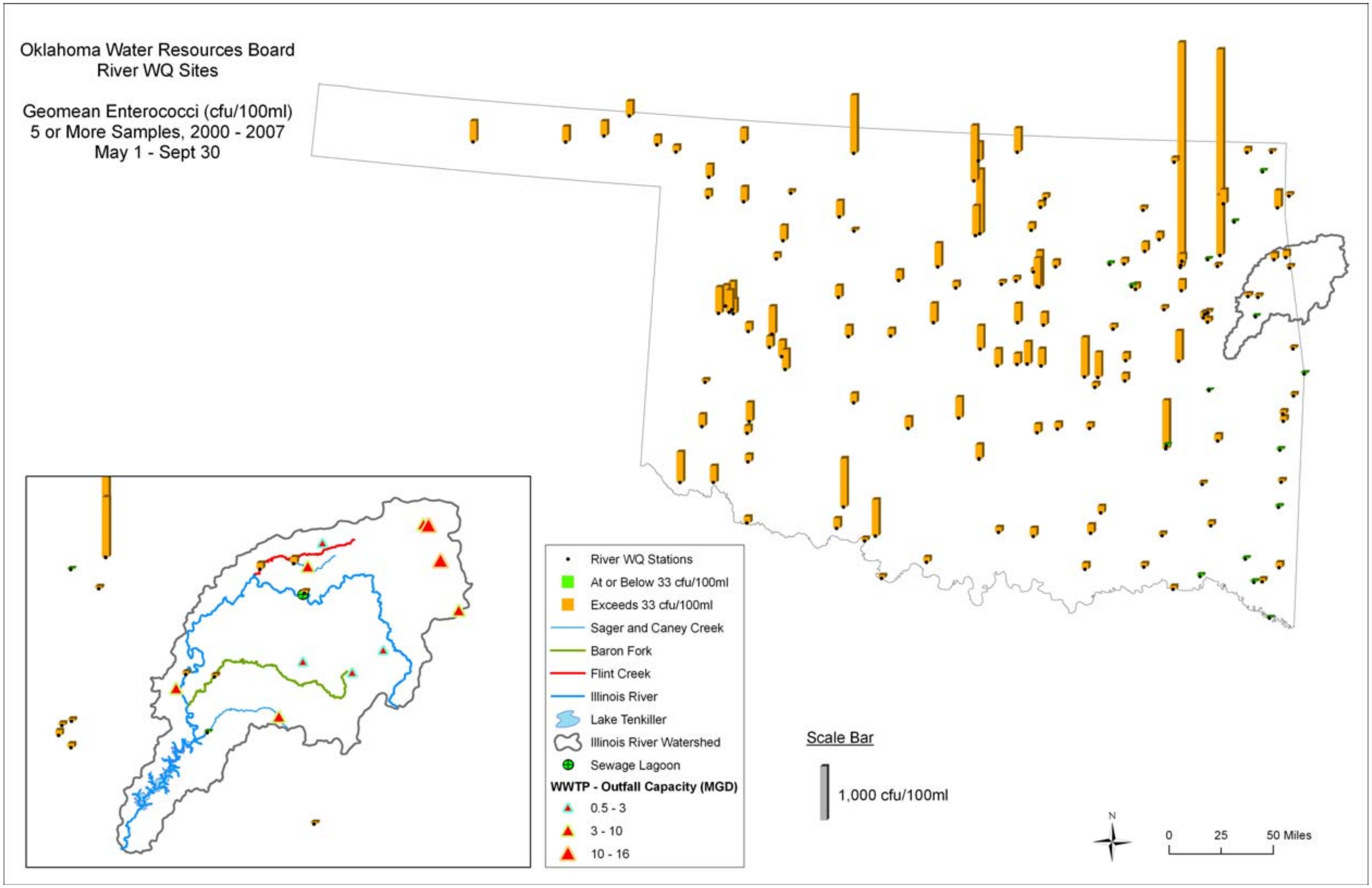

Figure 2-7. Map showing the geomean of enterococcus bacteria concentrations measured at all sites in Oklahoma represented in OWRB's database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

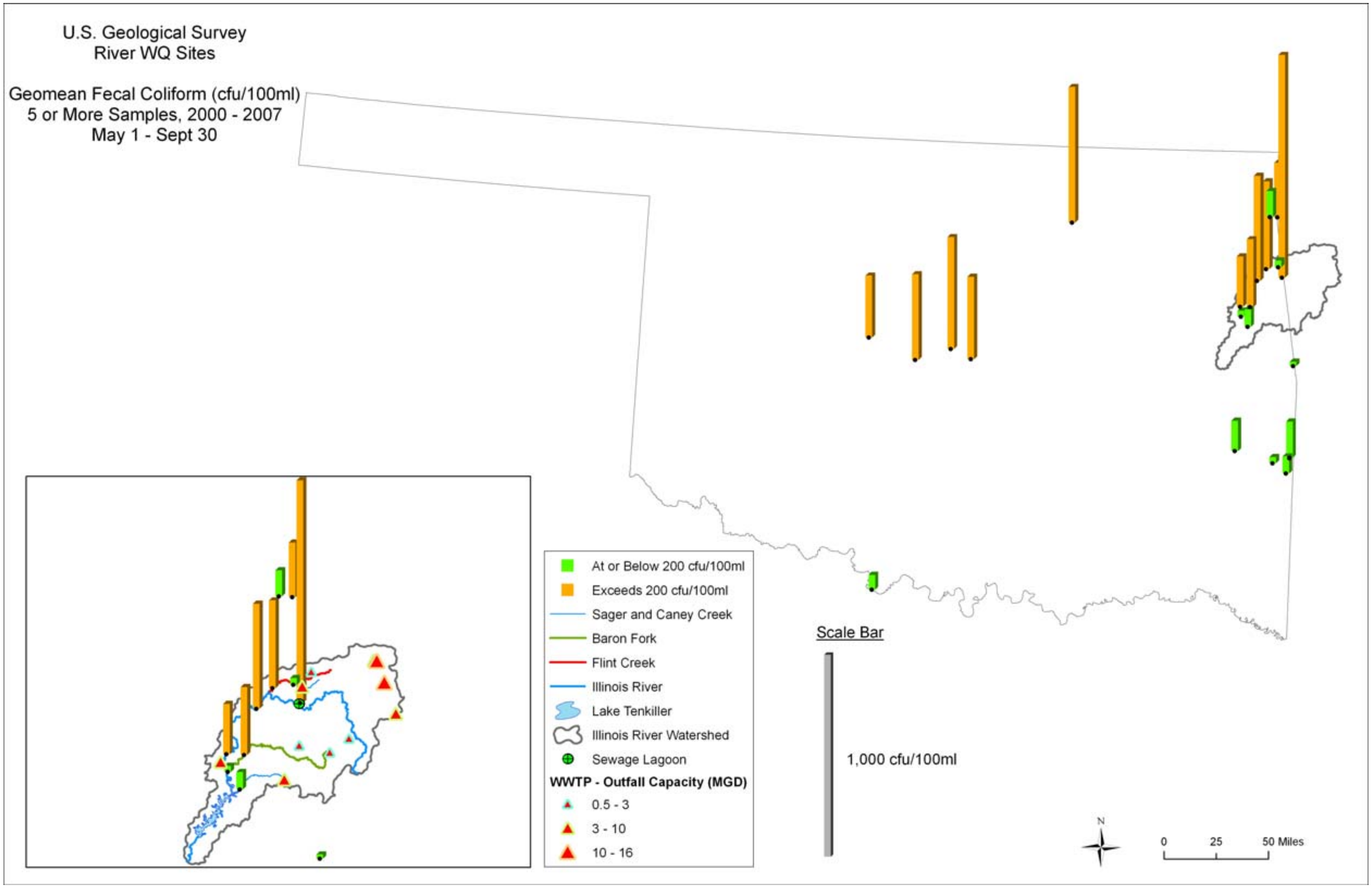

Figure 2-8. Map showing the geomean of fecal coliform bacteria concentrations measured at all sites in Oklahoma represented in USGS's database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green. Note that because relatively few sites within Oklahoma were sampled by USGS, these data are not particularly helpful on their own in evaluating statewide patterns.

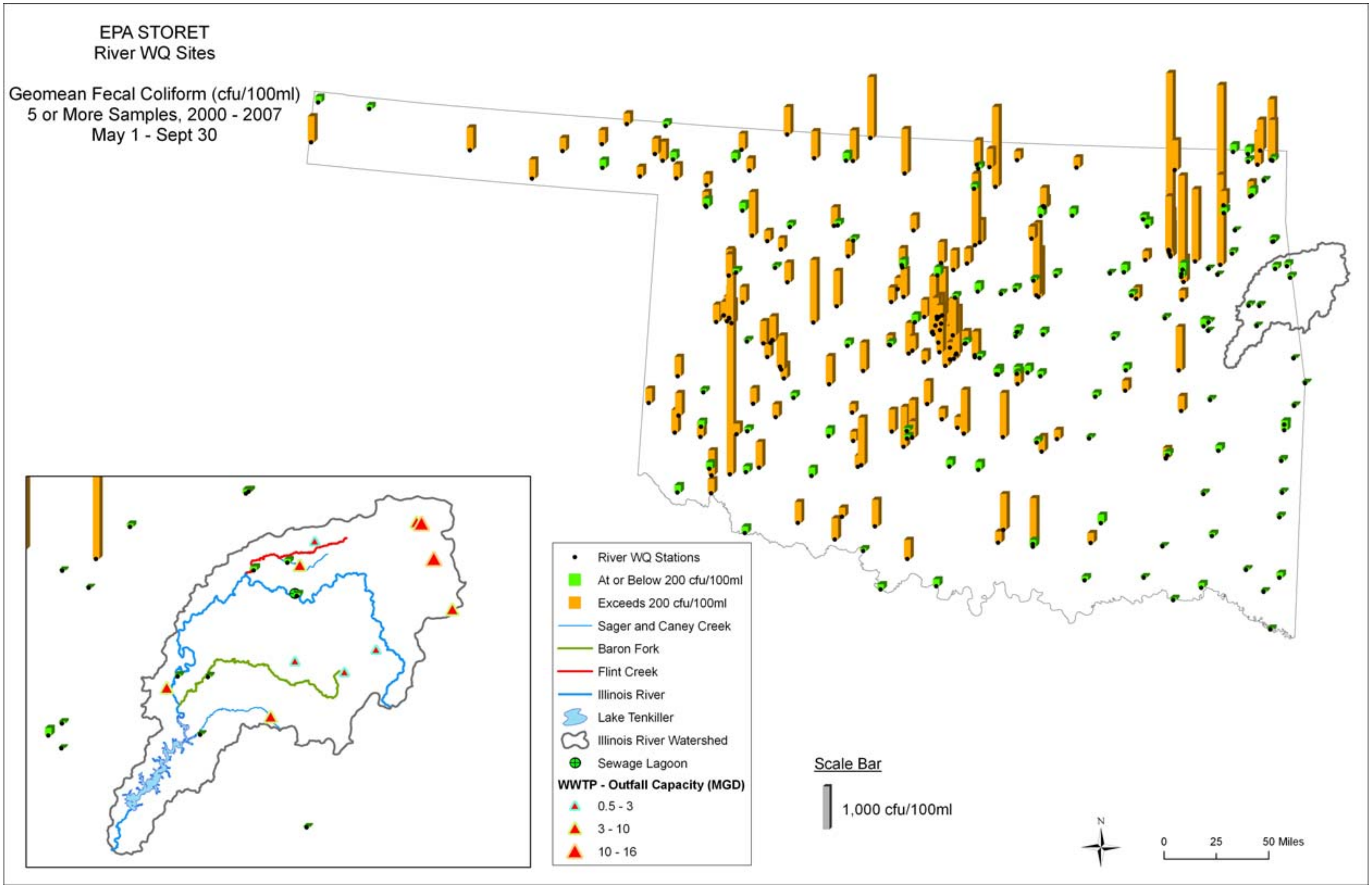

Figure 2-9. Map showing the geomean of fecal coliform bacteria concentrations measured at all sites in Oklahoma represented in EPA's STORET database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

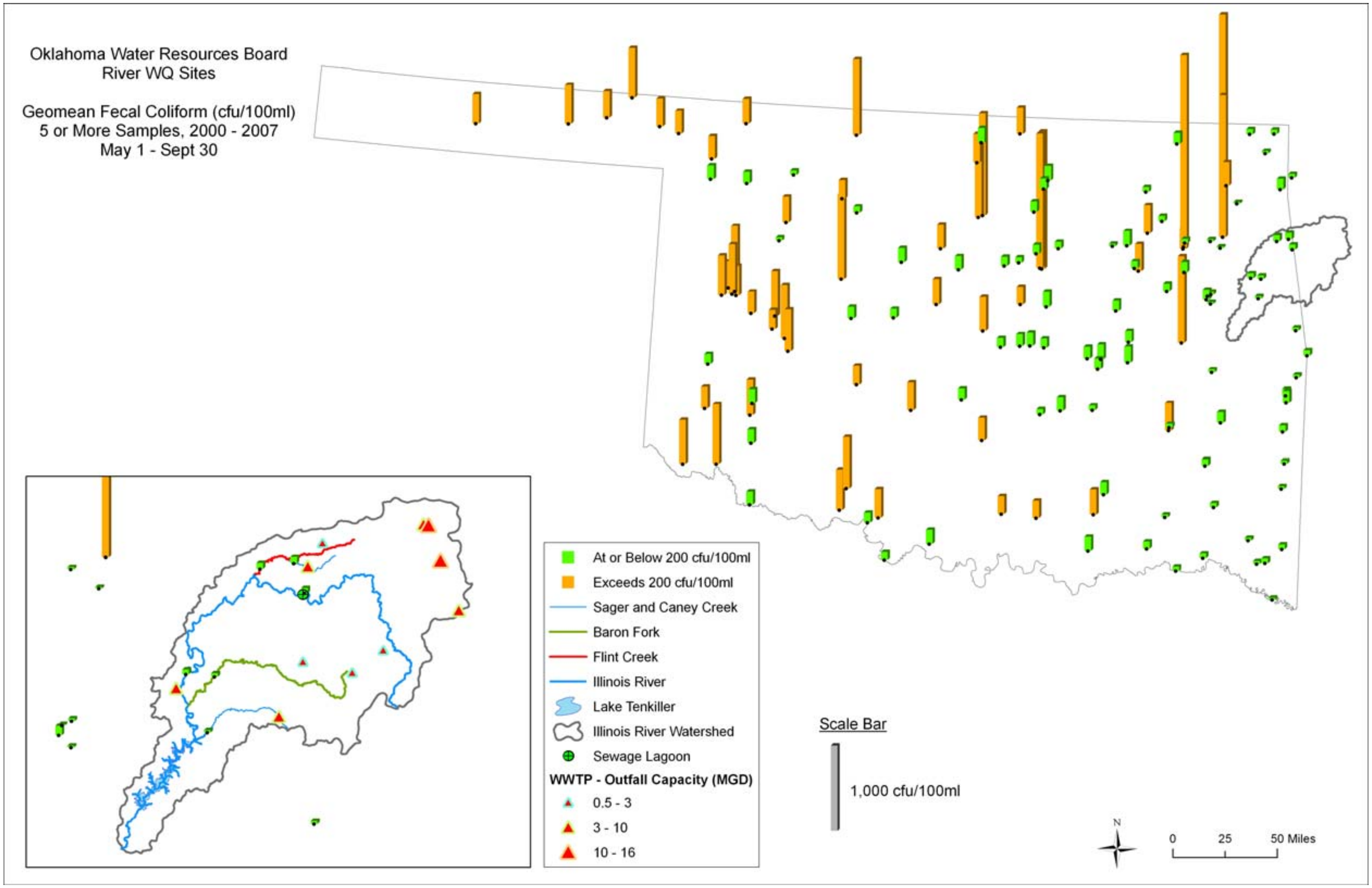

Figure 2-10. Map showing the geomean of fecal coliform bacteria concentrations measured at all sites in Oklahoma represented in OWRB's database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

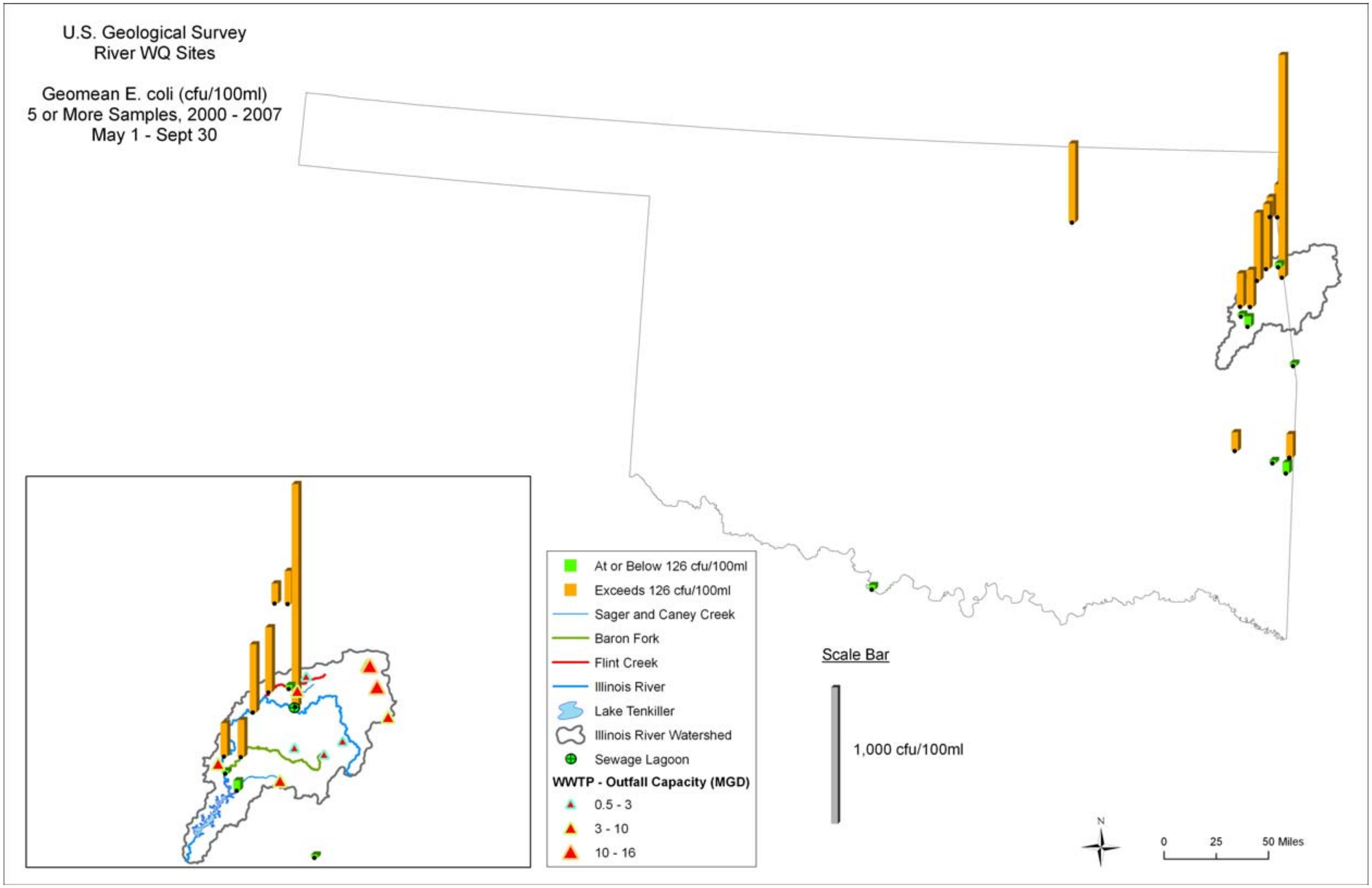

Figure 2-11. Map showing the geomean of *E. coli* concentrations measured at all sites in Oklahoma represented in USGS's database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green. Note that because relatively few sites within Oklahoma were sampled by USGS, these data are not particularly helpful on their own in evaluating statewide patterns.

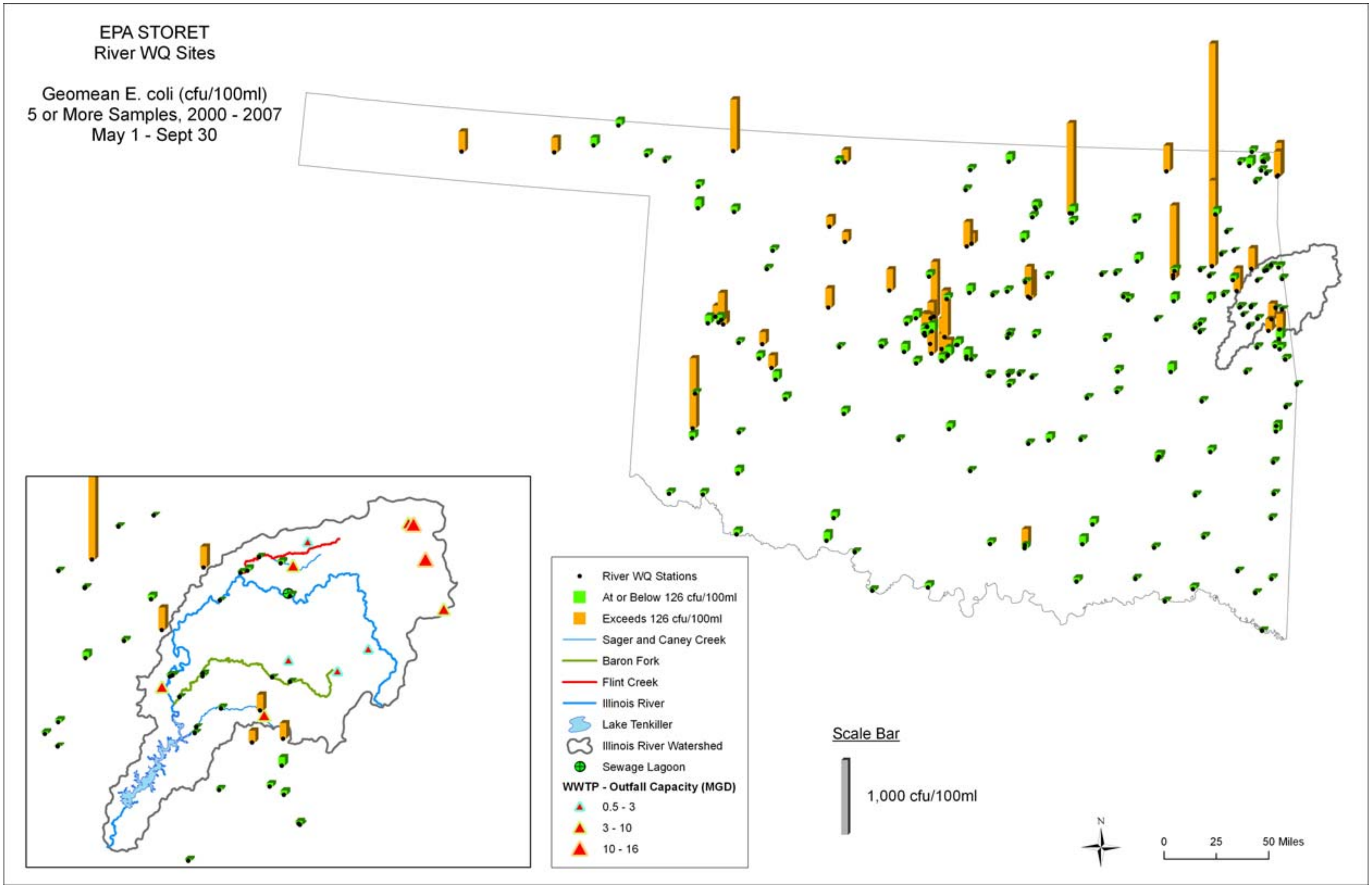

Figure 2-12. Map showing the geomean of *E. coli* concentrations measured at all sites in Oklahoma represented in EPA's STORET database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

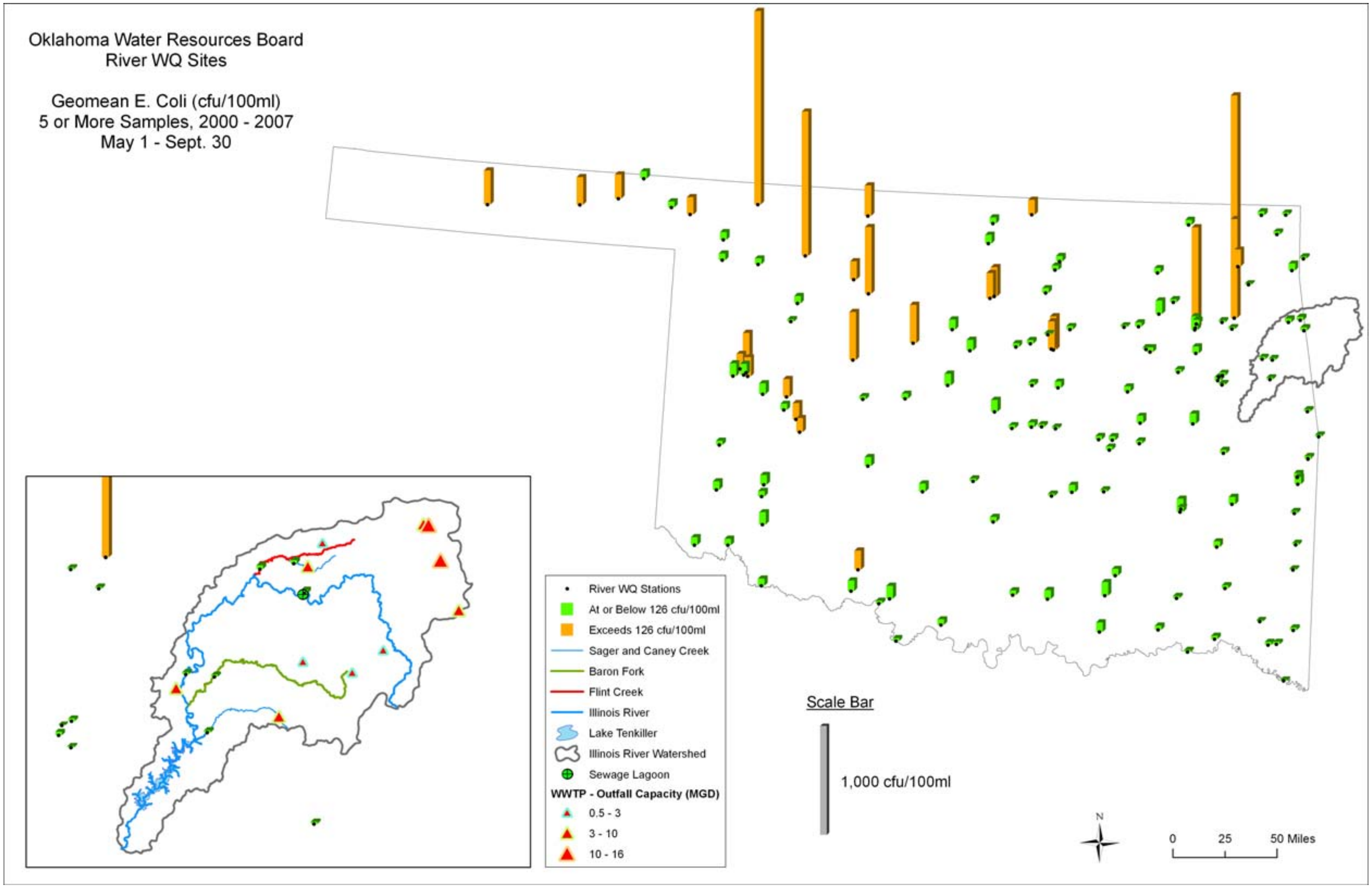

Figure 2-13. **Map showing the geomean of *E. coli* concentrations measured at all sites in Oklahoma represented in OWRB's database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.**

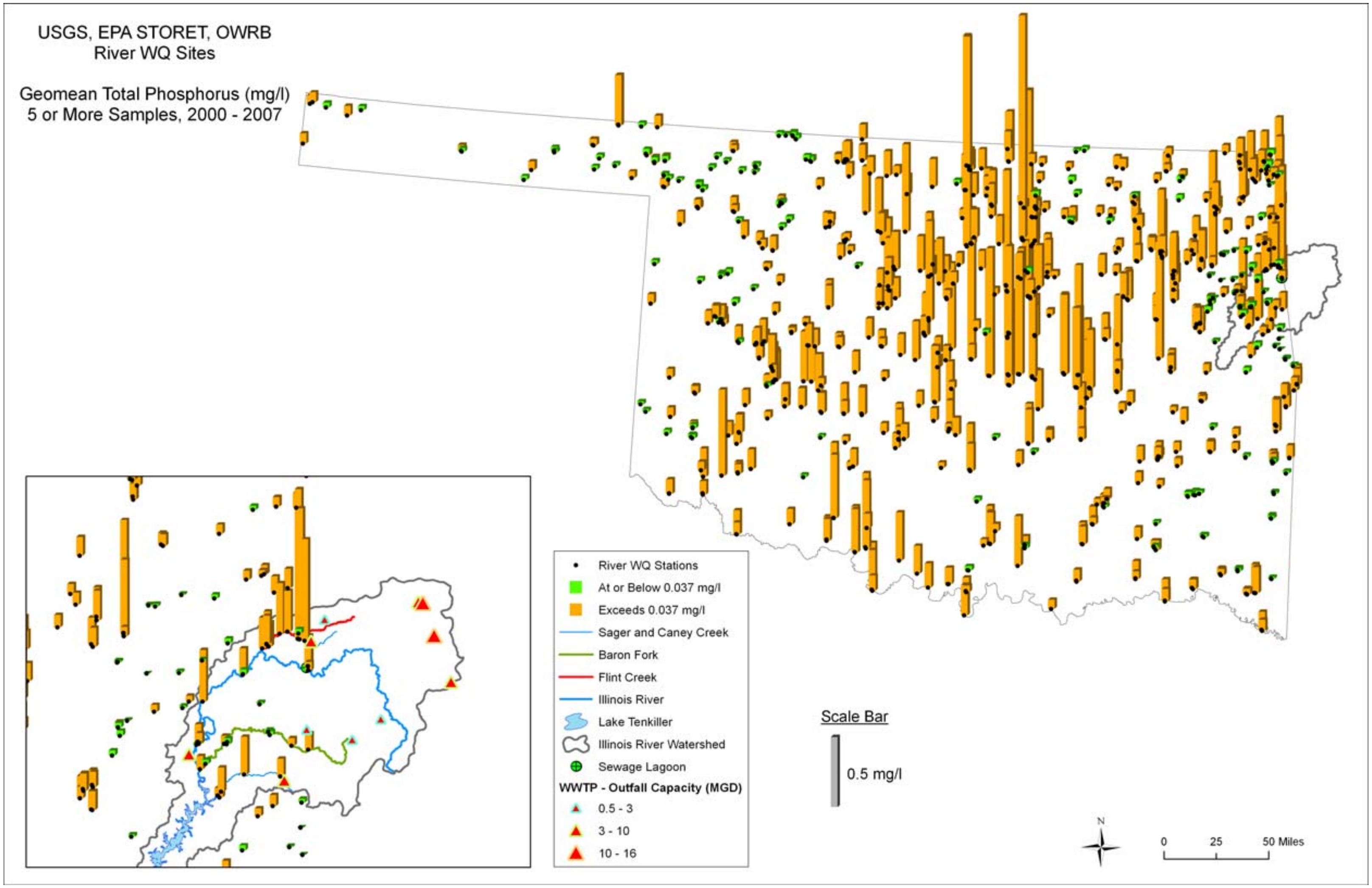

Figure 2-14. **Map showing the geomean of total phosphorus concentration measured at all sites in Oklahoma represented in USGS's, EPA's STORET, and OWRB's databases by five or more samples. The height of each bar is proportional to the geomean concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the 0.037 mg/L standard are shown in orange; those that do not exceed the standard are shown in green. The four highest bars within the IRW are all located on Sager Creek, between approximately 1.5 and 3 miles below the Siloam Springs WWTP.**

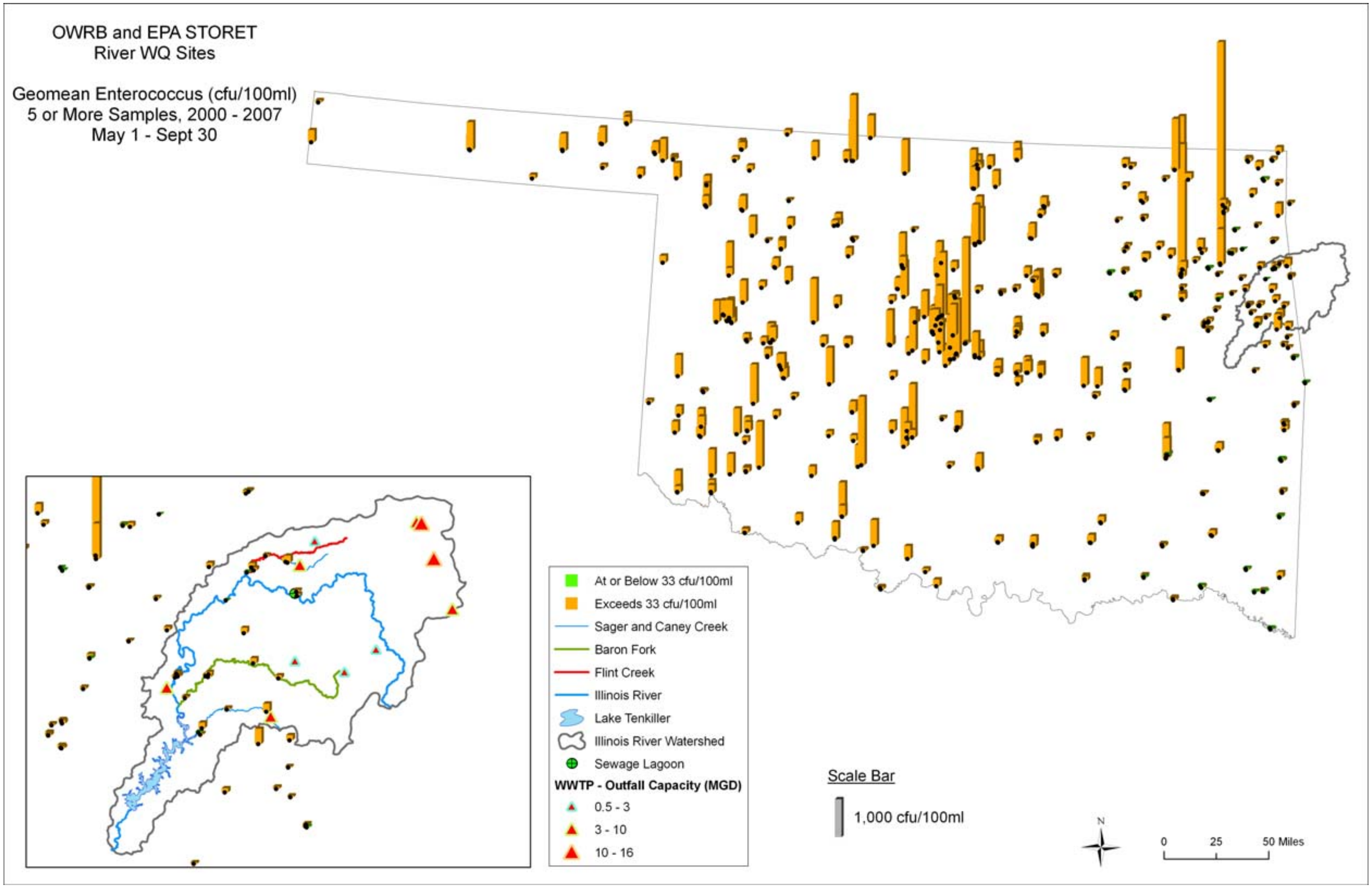

Figure 2-15. Map showing the geomean of enterococcus concentrations measured at all sites in Oklahoma represented in OWRB's and EPA's STORET databases by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

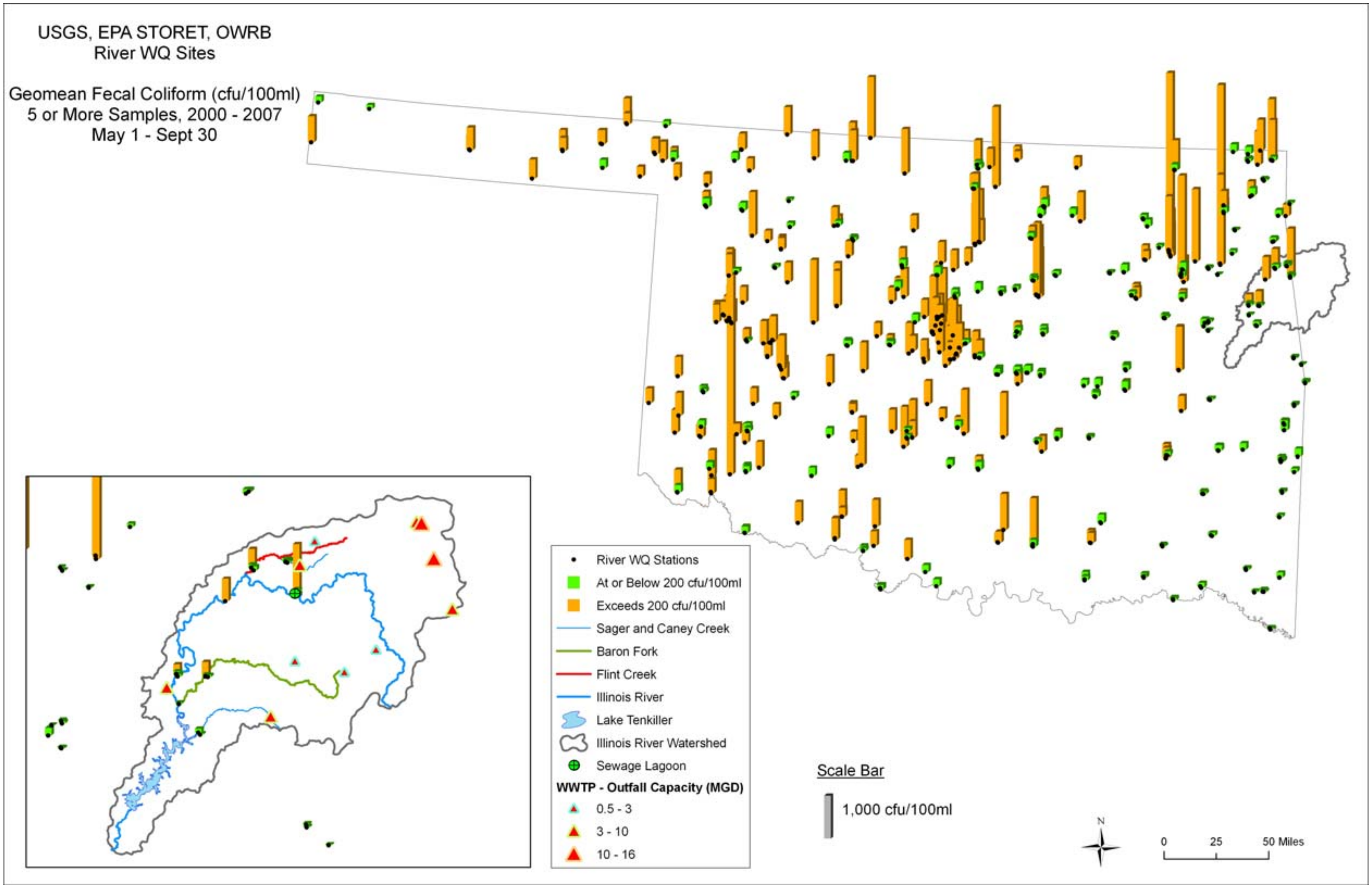

Figure 2-16. Map showing the geomean of fecal coliform bacteria concentrations measured at all sites in Oklahoma represented in USGS's, EPA's STORET, and OWRB's databases by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green. The highest bar within the IRW is located directly adjacent to the sewage lagoon at Watts, OK.

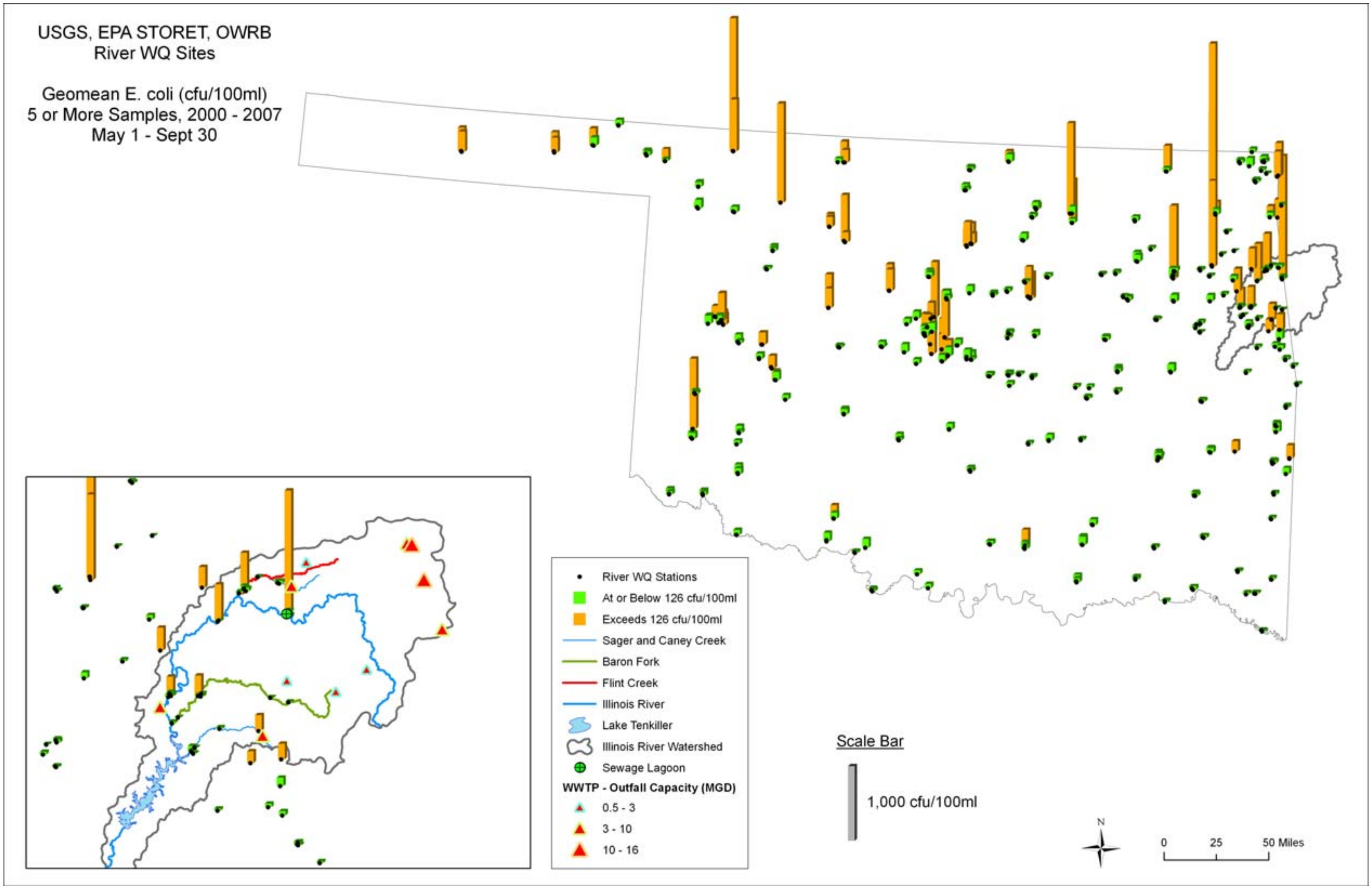

Figure 2-17. **Map showing the geomean of *E. coli* concentrations measured at all sites in Oklahoma represented in USGS's, EPA's STORET, and ORWB's databases by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green. The highest bar within the IRW is located directly adjacent to the sewage lagoon at Watts, OK.**

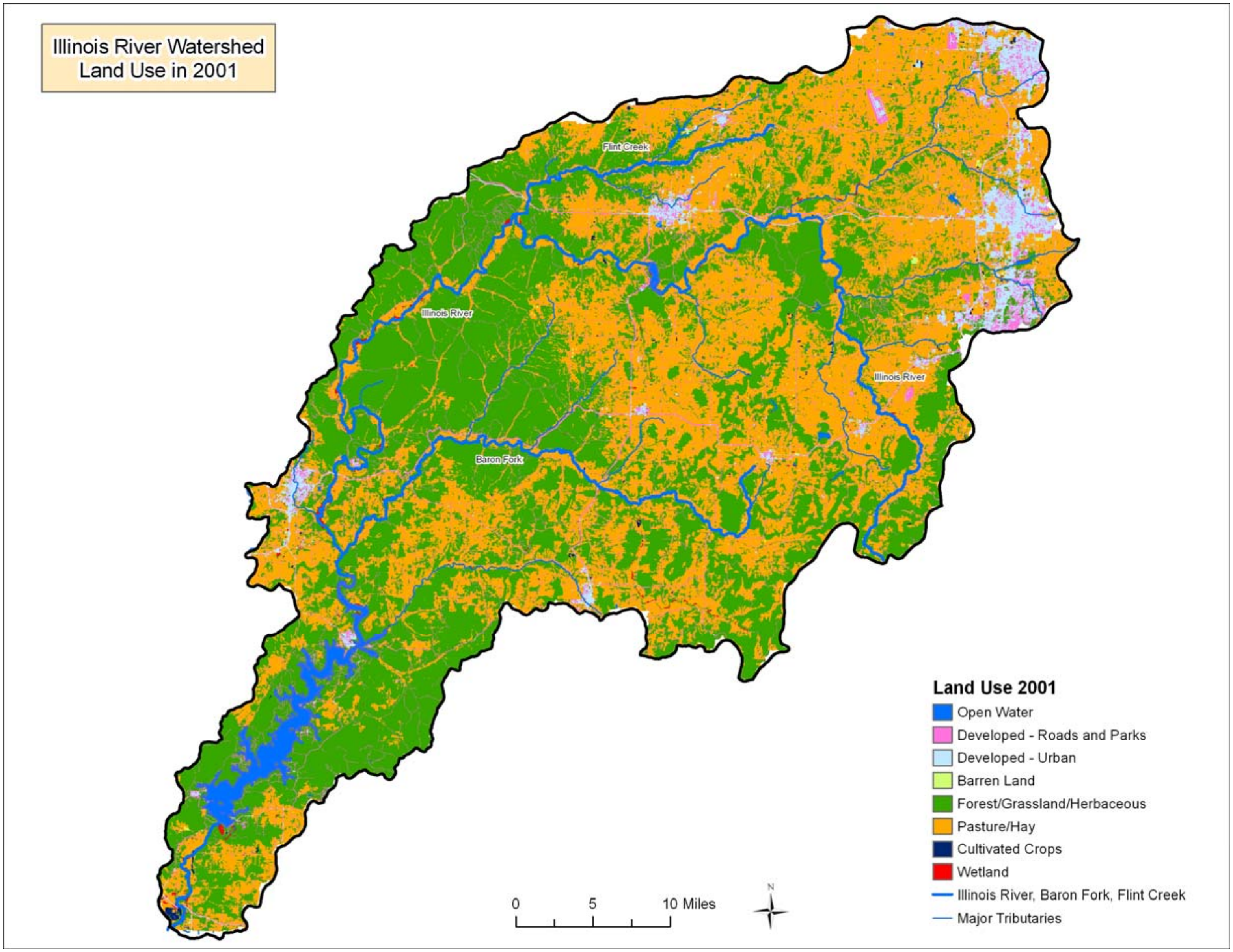

Figure 3-1. Land use in the Illinois River watershed. (Source: EPA's 2001 National Land Cover Dataset [NLCD])

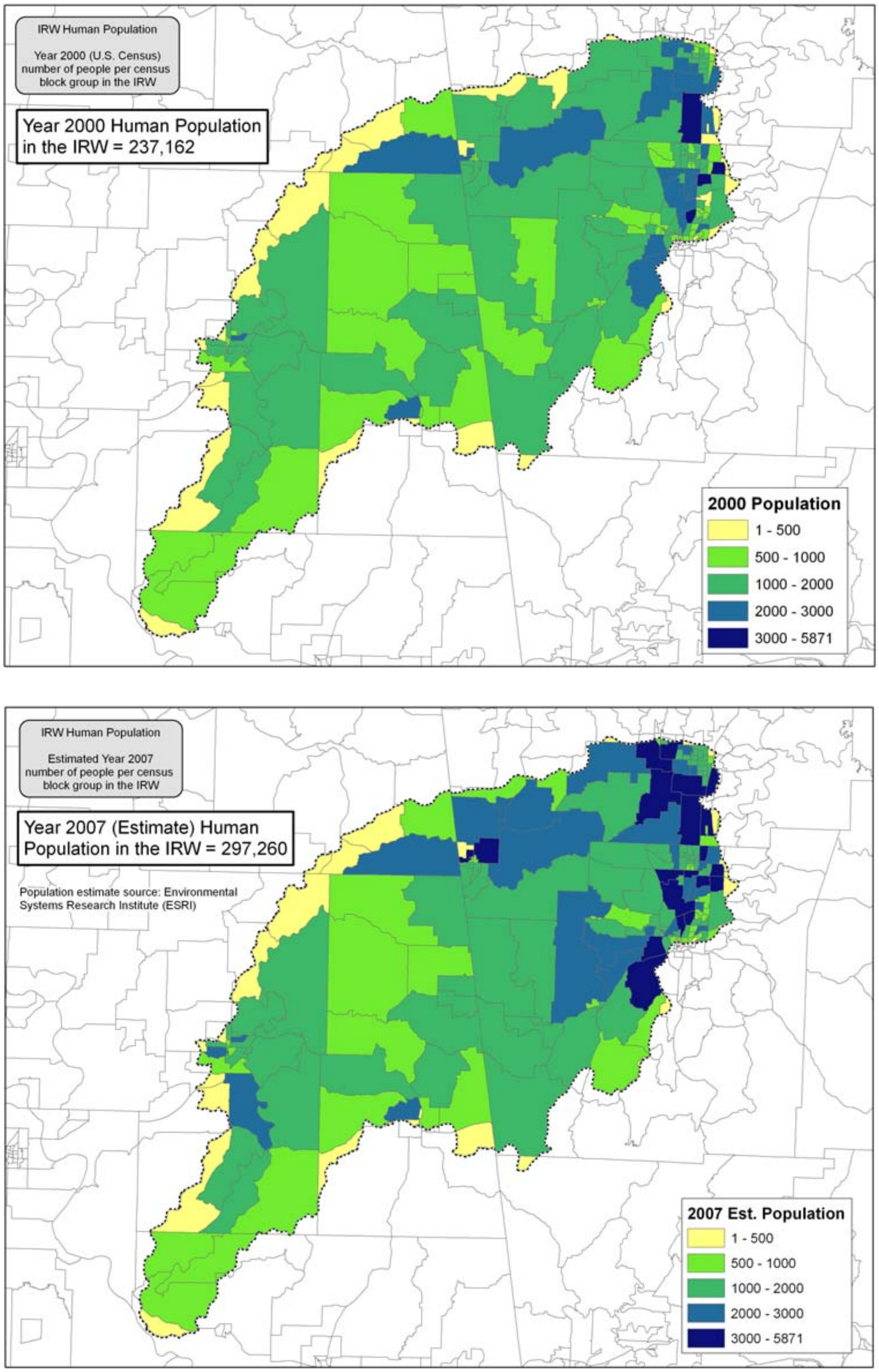

Figure 4-1. Estimated human population in the IRW in 2000 (top panel) and 2007 (bottom panel), by census block. For census blocks located along the perimeter of the IRW, the percent of people within the census block was estimated proportionally as the percent of the census block area that lies within the IRW boundaries. Note the marked increase in the human population from 2000 (237,000 people) to 2007 (297,000 people), especially near Tahlequah and in the upper reaches (northeast section) of the IRW in Arkansas.

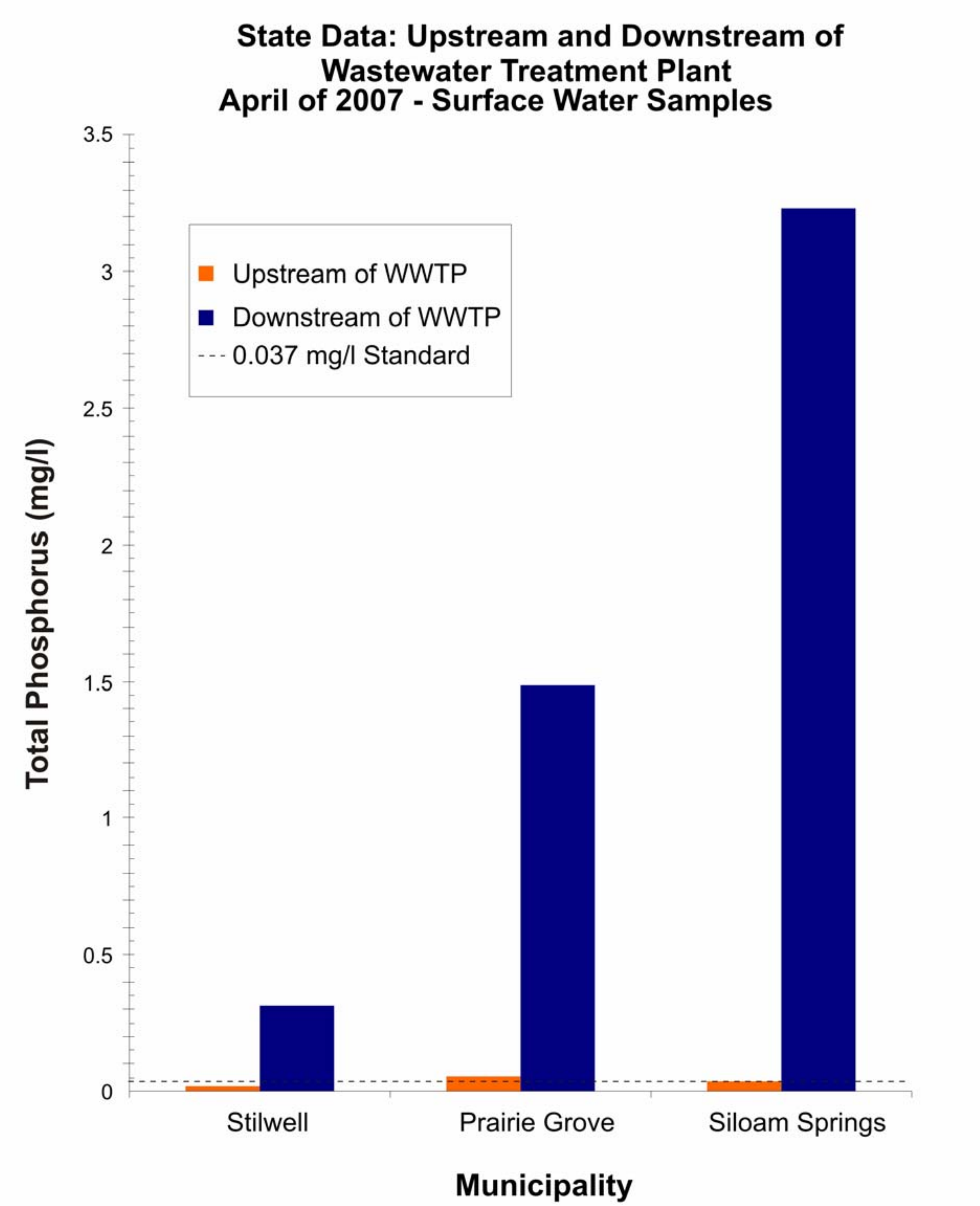

Figure 5-1. Measured total P concentration immediately upstream and downstream from WWTPs in the IRW, based on Plaintiffs' data collected in 2007. (Source: Olsen's Illinois Master Database)

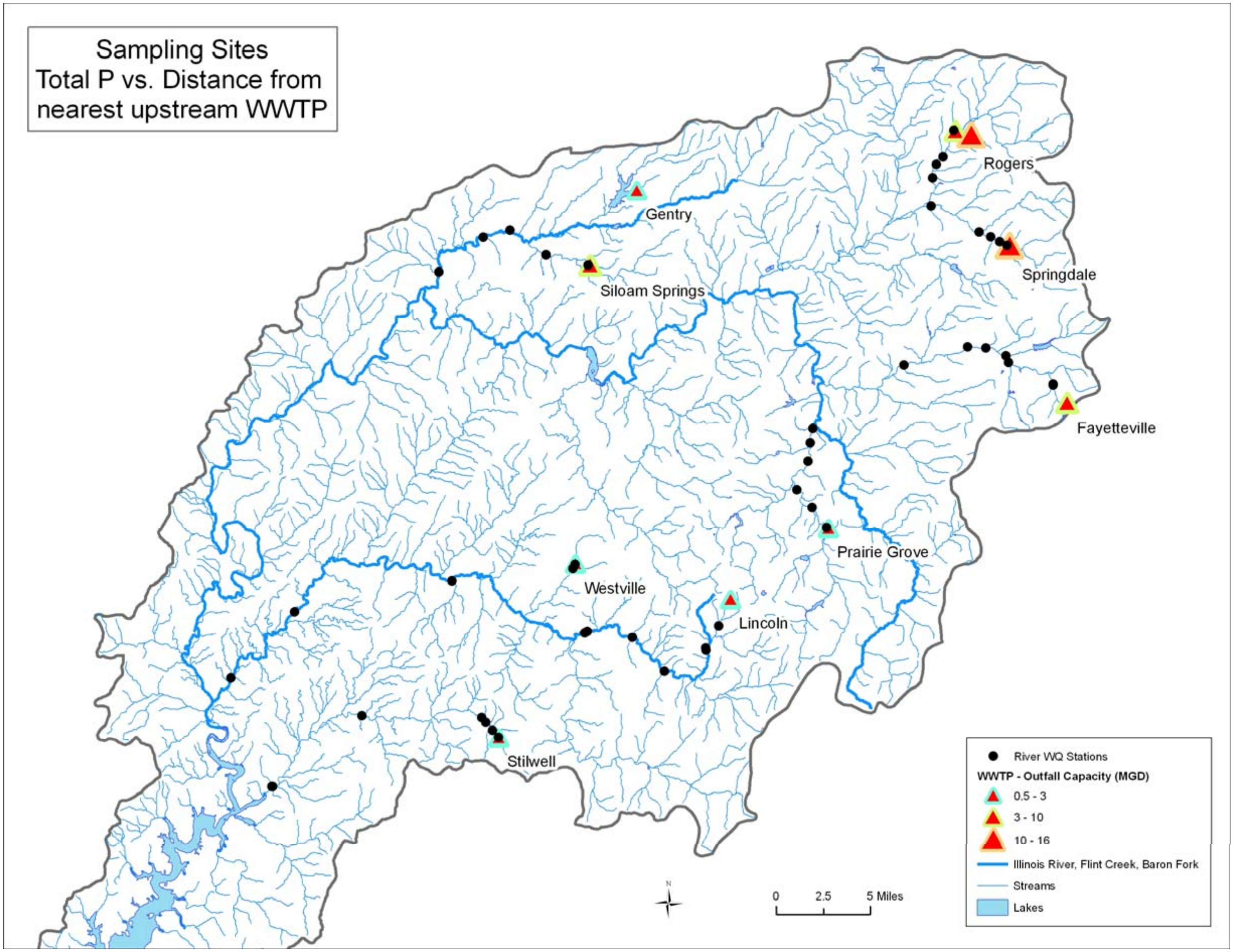

Figure 5-2. Locations of Plaintiffs' sampling sites and WWTPs represented by data shown in Figure 5-3. (Source: Olsen's Illinois Master Database)

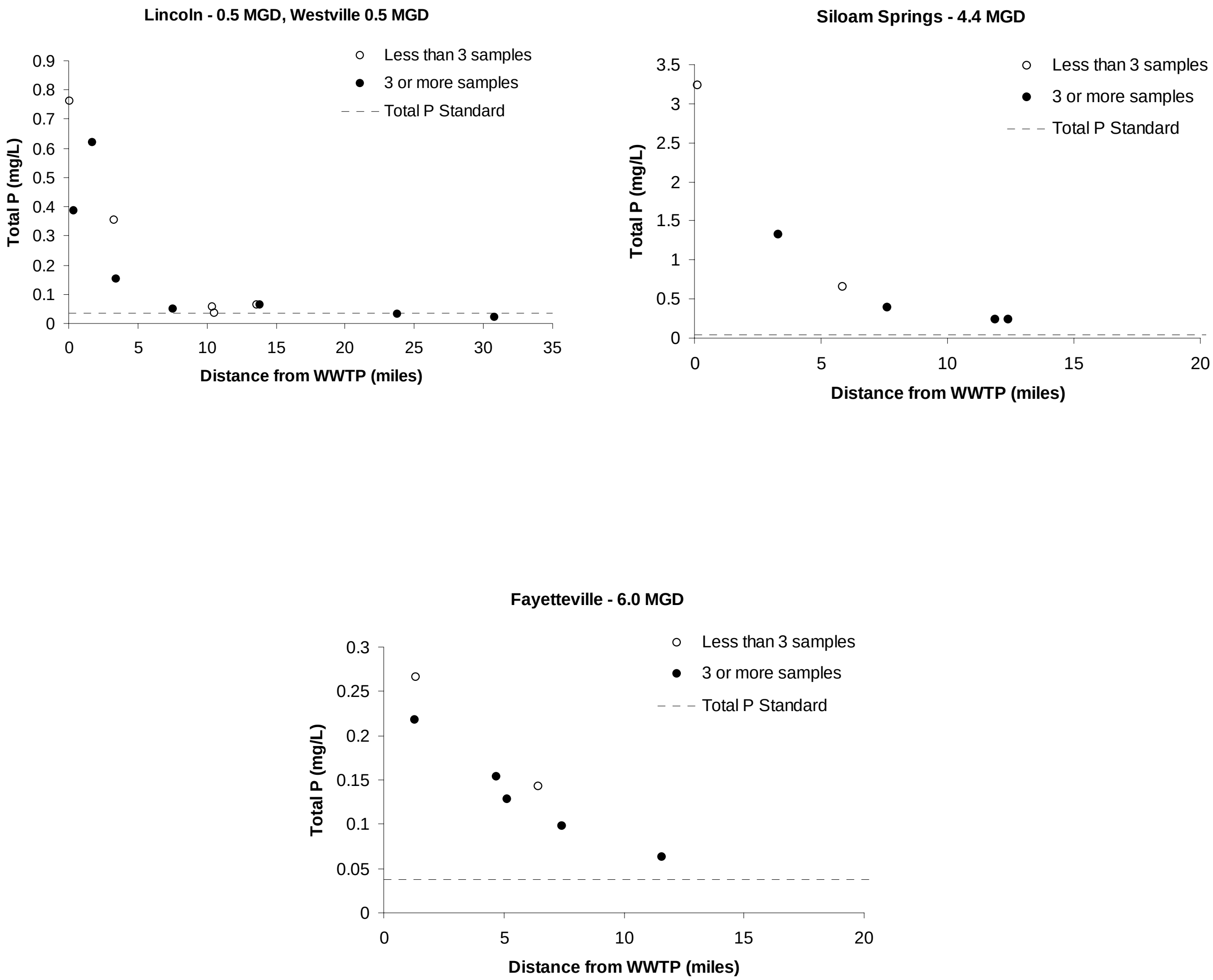

Figure 5-3. Concentrations of TP in streamwater versus distance from nearest upstream waste water treatment plant at sites located downstream from waste water treatment plants in the IRW. Geomean TP concentration is plotted at each site, coded by number of samples available. (Source of data: Olsen's Illinois Master Database)

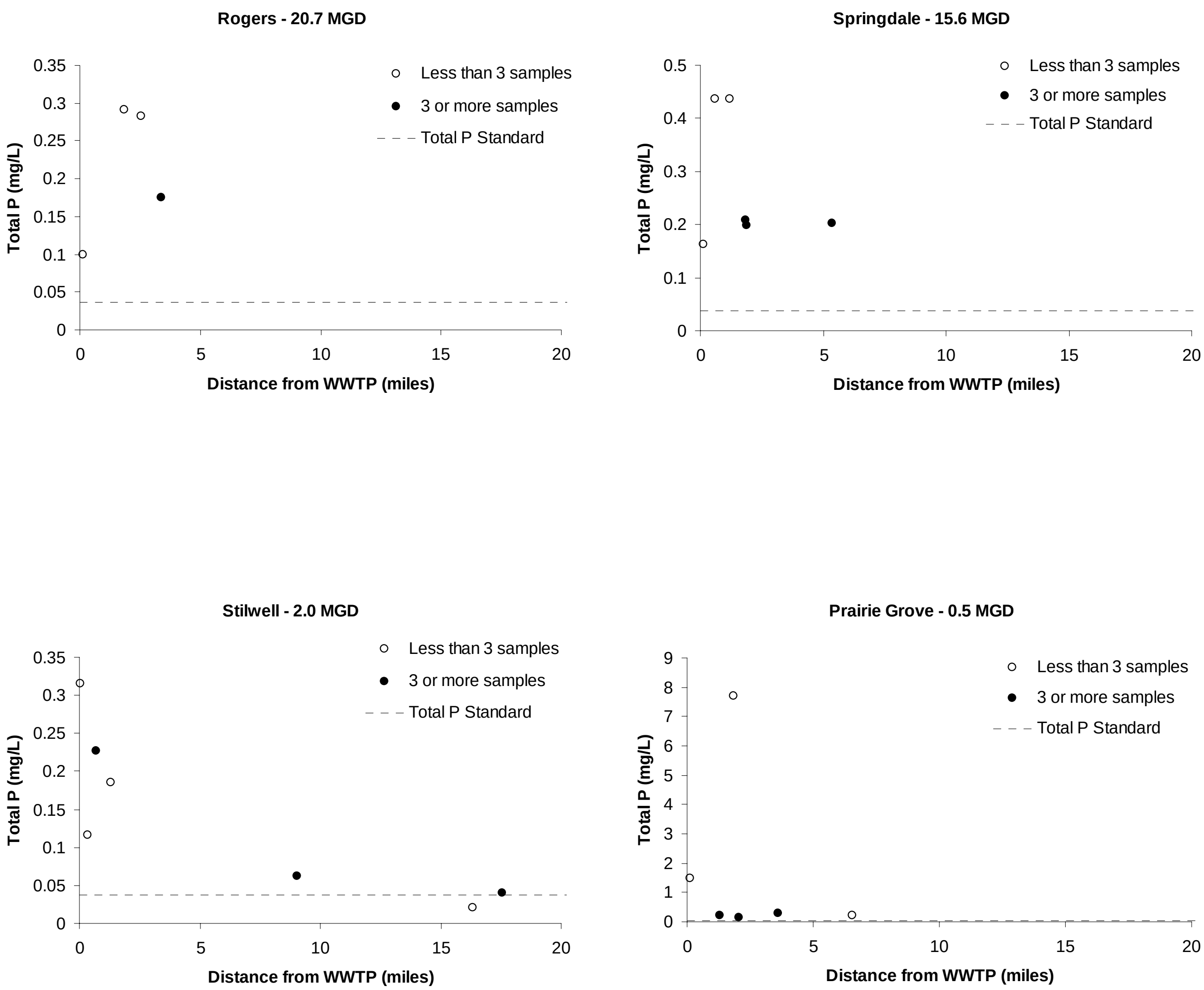

Figure 5-3. Continued.

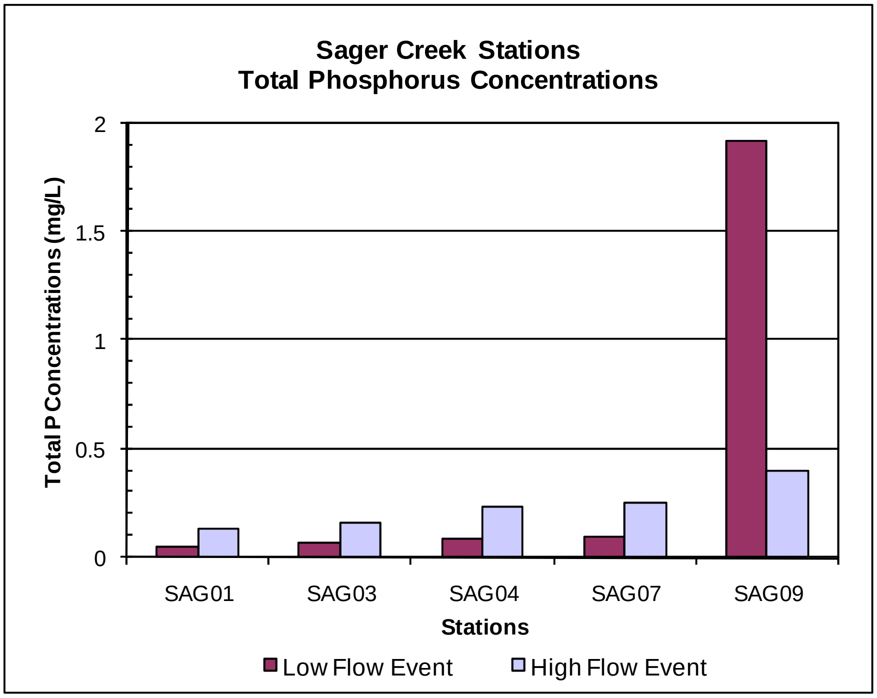

Figure 5-4. Concentrations of total P at stream sampling sites on Sager Creek and its tributaries located above (sites SAG01, SAG03, SAG04, and SAG07) and immediately below (site SAG09) the Siloam Springs wastewater effluent discharge point during a low-flow period (June 28, 1994) and a high-flow period (November 16, 1993). Source: redrawn from screengrab of figure presented in ADPCE (1995).

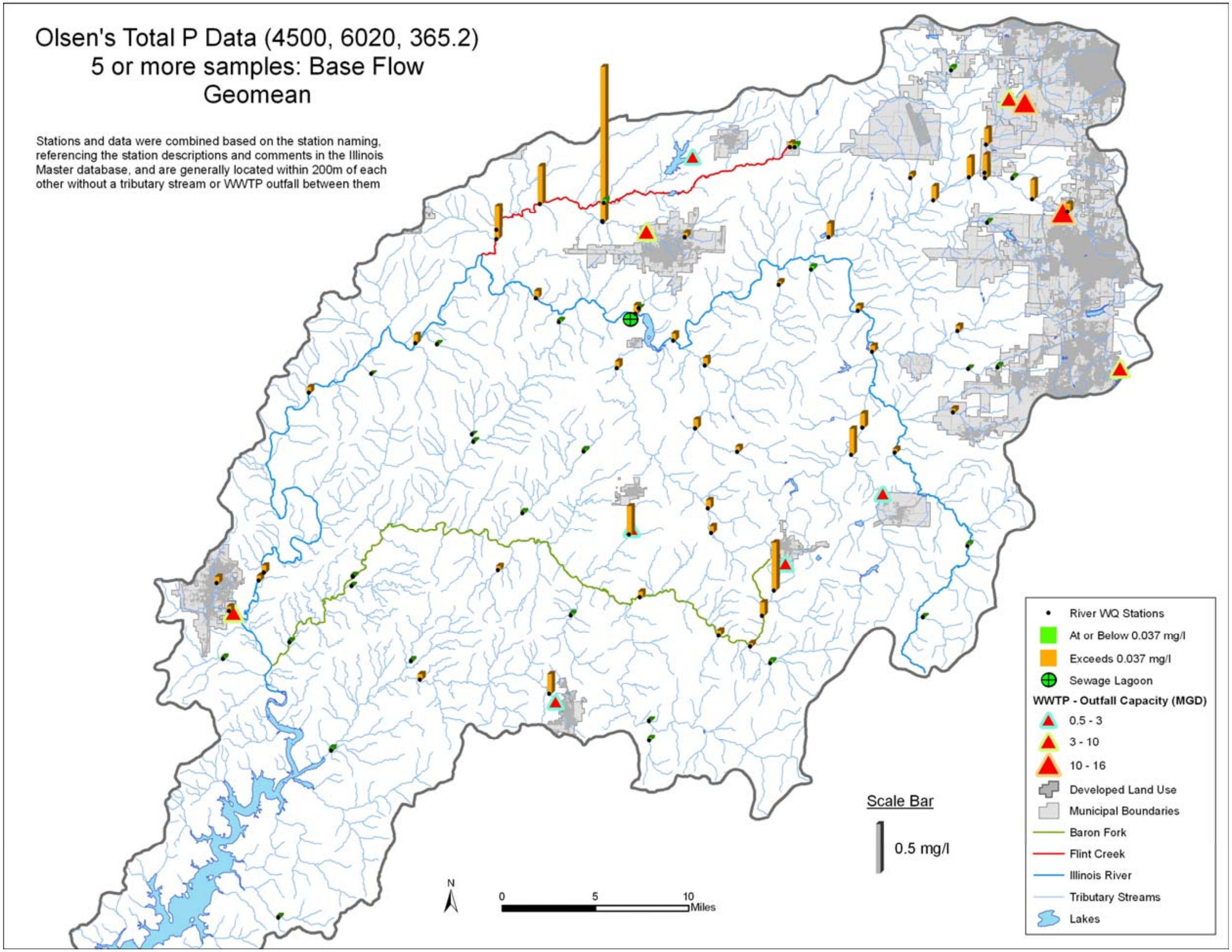

Figure 5-5. Map showing Plaintiffs' stream total P concentrations, WWTPs, and municipal boundaries and urban land use in the Illinois River watershed under BASE FLOW as identified by Dr. Olsen. Data are reported as the geomean for locations having 5 or more samples.

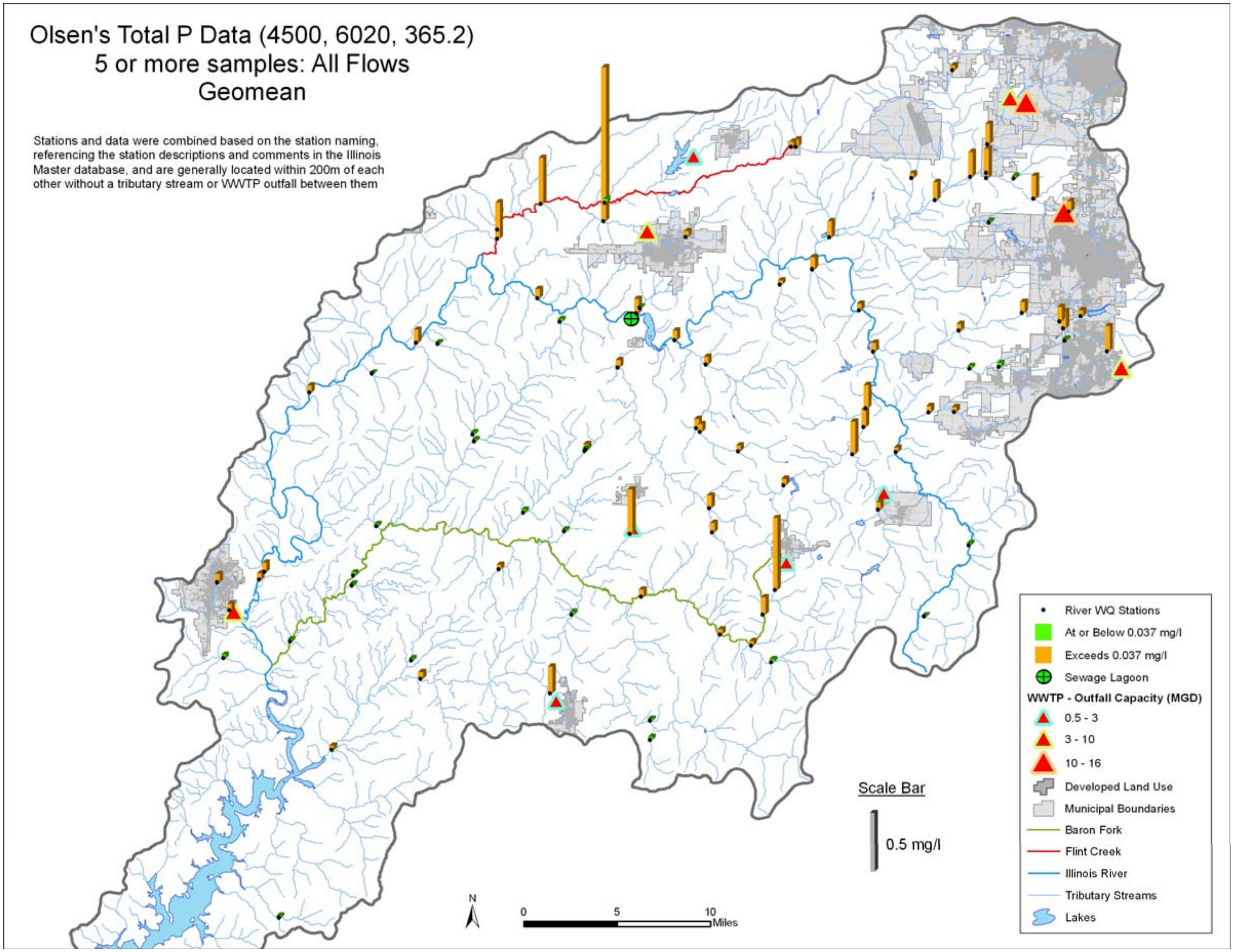

Figure 5-6. **Map showing stream total P concentrations and urban land use in the Illinois River watershed. Geomean total P concentrations from the Plaintiffs' database are depicted as vertical bars, with bar height proportional to the geomean measured total P concentration at each water quality monitoring site. Urban areas and municipal boundaries are indicated. Wastewater treatment plant outflows are indicated, the size of symbol indicating the capacity of the treatment facility.**

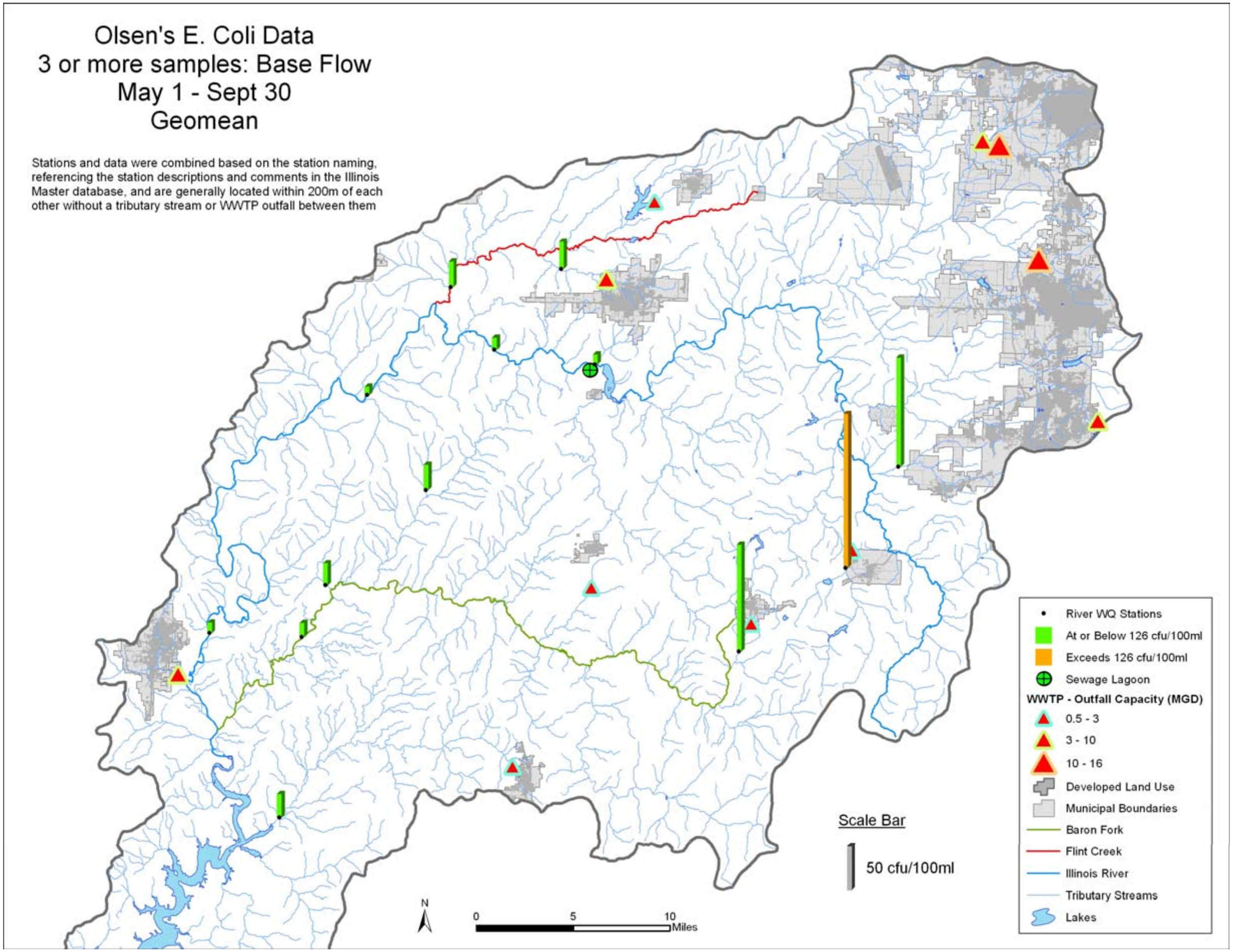

Figure 5-7. Map showing Plaintiffs' stream *E. coli* concentrations, WWTPs, and municipal and urban land use in the Illinois River watershed under BASE FLOW. Data are reported as the geomean for locations having 3 or more samples.

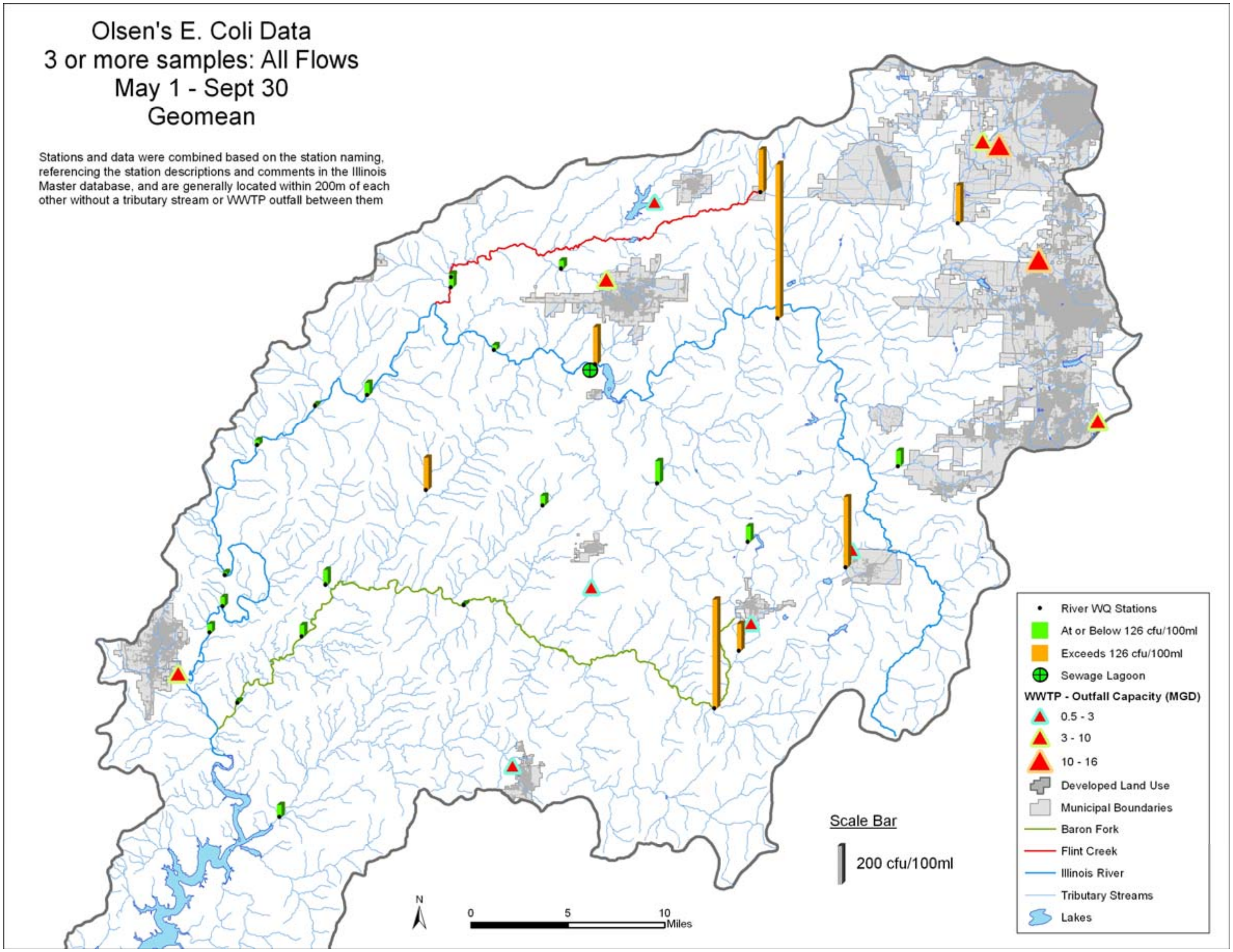

Figure 5-8. **Map showing stream *E. coli* concentrations in the Illinois River watershed under all flow conditions. Geomean *E. coli* concentrations from Plaintiffs' database are depicted as vertical bars, with bar height proportional to the geomean measured total P concentration at each water quality sampling location. Urban areas and municipal boundaries are indicated. Wastewater treatment plant outflows are indicated, the size of symbol indicating the capacity of the treatment facility.**

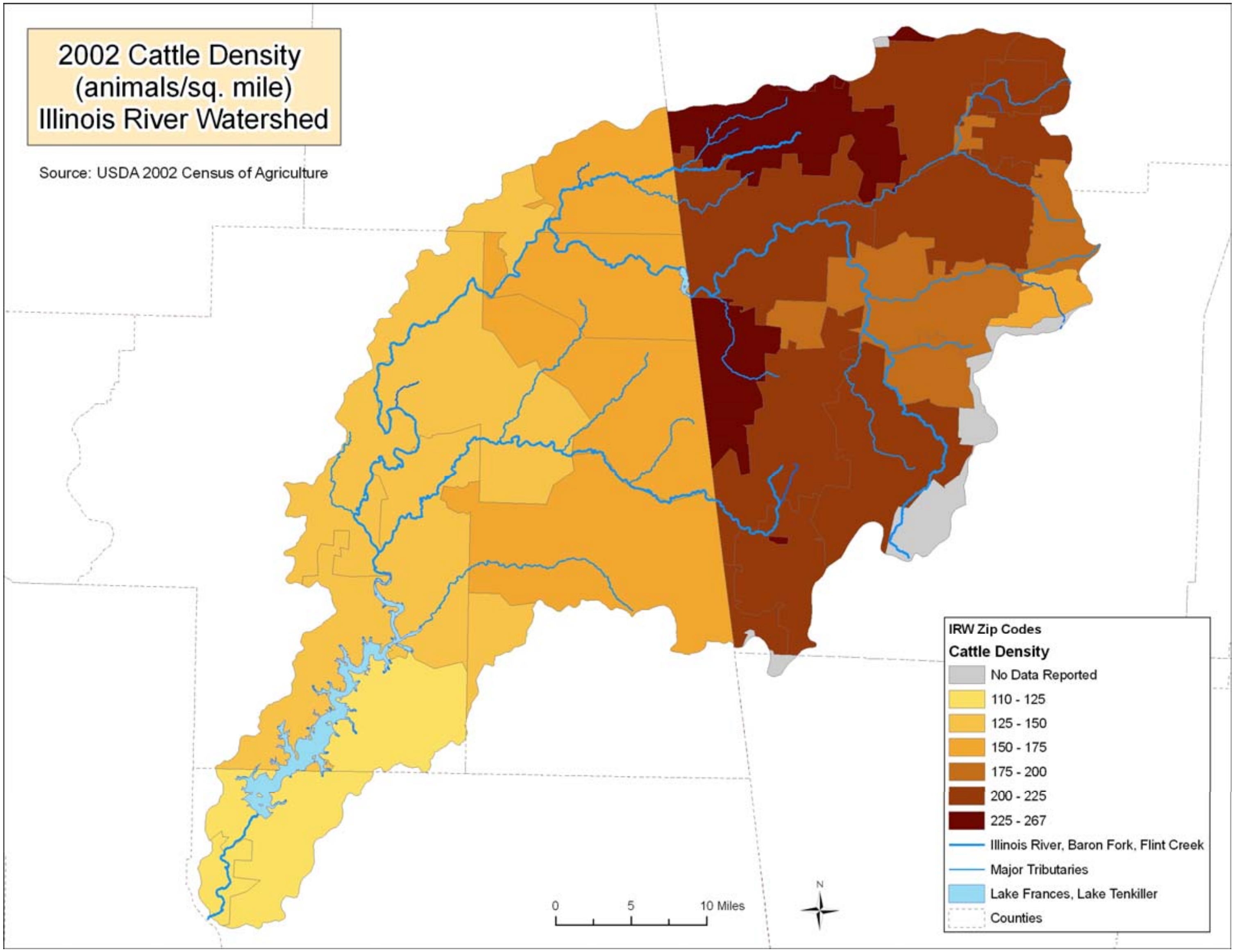

Figure 6-1. Map of cattle (including beef and milk animals) distribution by zip code within the Illinois River watershed. Densities in the immediate vicinity of four communities (Fayetteville, Rogers, Tontitown, and Tahlequah) may be biased low because we have not been able to obtain the boundaries for four new zip codes in those communities. (Source: 2002 Census of Agriculture and Dr. Billy Clay)

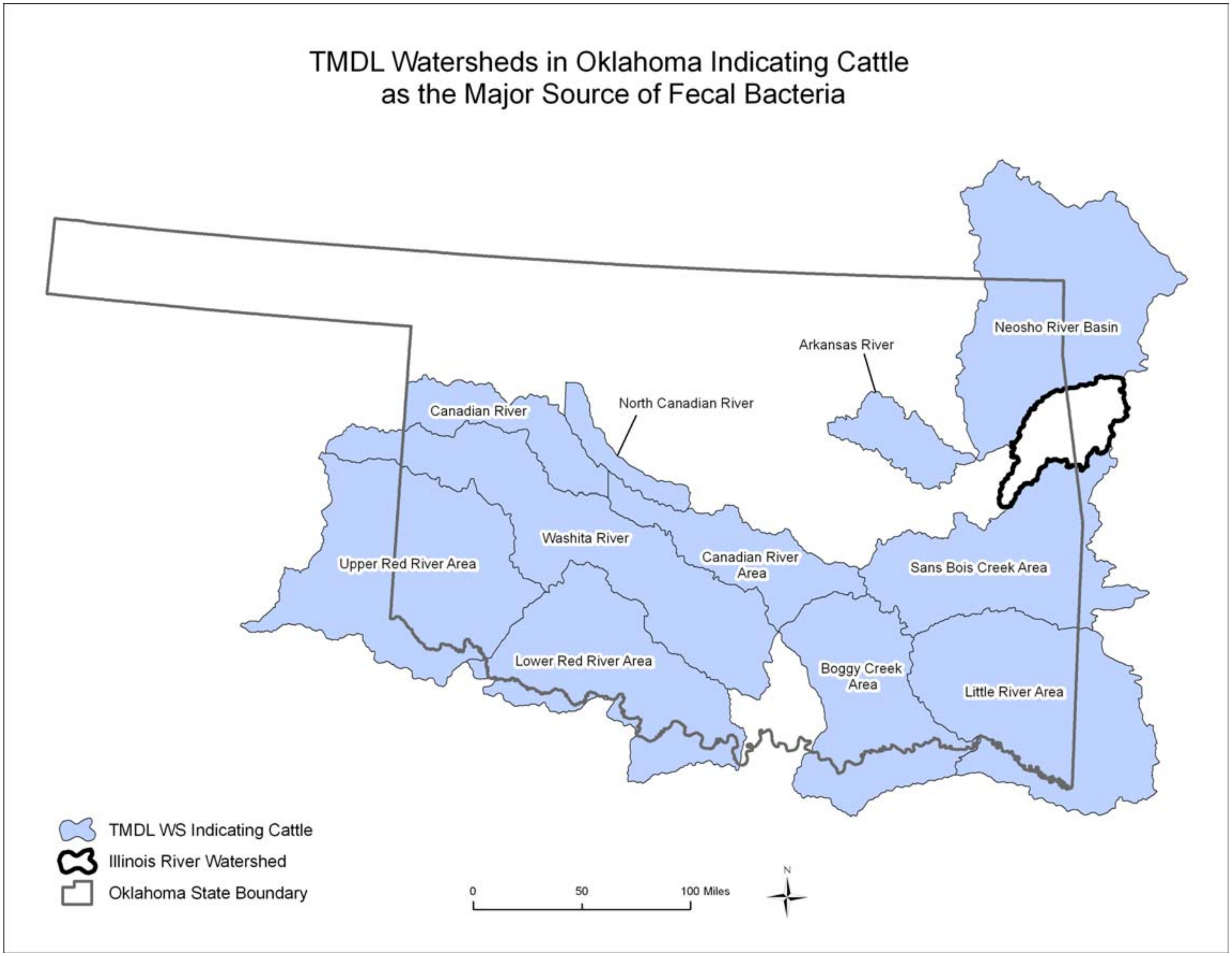

Figure 6-2. **Watersheds in Oklahoma for which a bacterial TMDL has been completed for the Oklahoma Department of Environmental Quality and for which the TMDL indicated a major source of fecal bacteria. In all 11 cases, the indicated major source was cattle. Also shown is the location of the IRW. (Source: USGS Hydrologic Unit Boundaries)**

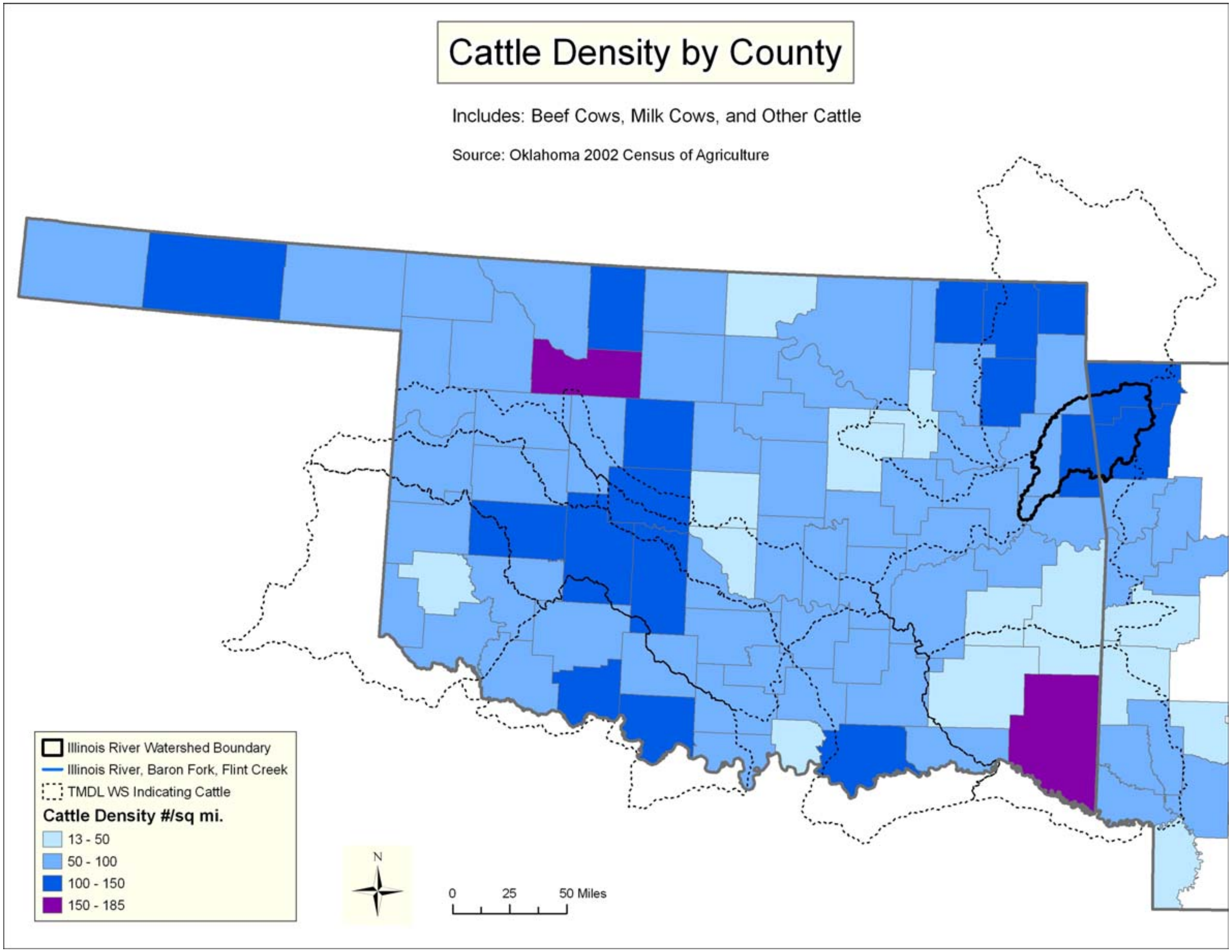

Figure 6-3. Cattle density by county throughout Oklahoma and northwestern Arkansas. Watershed boundaries are shown for the IRW and Oklahoma watersheds for which TMDL reports indicated that cattle constitute the primary source of fecal indicator bacteria to stream water.

Figure 7-1. Series of photos taken by Plaintiffs' consultants showing some of their edge of field sampling sites. Plaintiffs ask the court to accept their claims that 1) they know where the water flowed from, and furthermore that it all flowed from the pasture land; 2) poultry litter (rather than cattle manure, erosion, septic systems, and/or residential housing) is the main or the only source of P and other constituents in the sampled water; 3) that the sampled water would flow into a stream; and 4) that the water would flow into the stream in sufficient volume to appreciably change the water quality of that stream.